

# A Qualitative Case Study: Understanding the Mathematical Identity of Elementary Preservice Teachers

---

By  
Meaghan Pavlovich  
© 2019

Submitted to the graduate degree program in Curriculum and Teaching and the Graduate  
Faculty of the University of Kansas in partial fulfillment of the requirements for the degree  
of Doctor of Education Ed.D.

---

Chair: Kelli Thomas, Ph.D.

---

Barbara Bradley, Ph.D.

---

Carrie La Voy, Ph.D.

---

Steven White, Ph.D.

---

Lisa Wolf-Wendel, Ph.D.

Date Defended: February 27, 2019

The dissertation committee for Meaghan Pavlovich certifies that this is the  
approved version of the following dissertation:

A Qualitative Case Study: Understanding the Mathematical Identity  
of Elementary Preservice Teachers

---

Chair: Kelli Thomas, Ph.D.

Date Approved: March 26, 2019

### **Abstract**

This qualitative case study examined the mathematical identities and perceptions of equity of eight female elementary preservice teachers in their junior year of a teacher preparation program at a Midwestern research university. Within the affective domain, beliefs related to competence, performance, and recognition, along with interest, were identified as the important factors shaping the mathematical identity of the participants. The prominence of these factors and the relationship between them was unique for each participant. Themes were identified through a cross participant analysis. Consistent between all of the factors and all of the participants was the influence of the teacher within the mathematics classroom. Furthermore, the participants' salient identities and experiences that shaped these factors influenced their perceptions related to equity. The participants' perceptions of equity related to gender norms and gender stereotypes, both inside and outside of the mathematics context, were a predominant theme. In addition, within the mathematics context, their perceptions of equity were shaped by their access to a high-quality curriculum, effective teaching and learning, and high expectations.

## Acknowledgments

As an educator my primary purpose has always been to make a difference in the lives of others. Since the day I started this process I have been looking forward to writing this section of my dissertation so that I can acknowledge and thank the people who have made a significant difference in my life. My heart is filled with gratitude.

To my committee members, Dr. Bradley, Dr. Huffman, Dr. La Voy, Dr. Thomas, Dr. White, and Dr. Wolf-Wendel, your expertise and wisdom pushed my thinking in ways that I never knew was possible. I hope that you each see your influence within this dissertation.

To my advisor, Dr. Thomas, thank you! I'm forever grateful for the day Dr. Mahlios introduced us. I knew then that I would be successful through this process because of you. You have provided me with countless hours of guidance and support. You gave me the space to adjust as needed and believed in me to figure it out. You truly invested in me, and most importantly, you allowed me to be me.

To Dr. La Voy, you generously shared hours of your time and opened up your classroom to me. During my first year in the doctoral program, you planted the seeds related to equity that later grew into this dissertation. It was because of you that I found the purpose and passion needed to complete something like this.

To Susan McGee, Graduate Admissions Coordinator for the Department of Curriculum and Teaching. Your email on July 11, 2013, informing me that I had been accepted to the doctoral program will always be the best email in my inbox. I truly appreciate all of the support you have provided throughout the last six years.

To the participants in this study, thank you for sharing your stories with me. I am in awe of each of you. You are thoughtful, kind, and committed to making a difference. You give me such hope for the next generation of educators.

To my husband, Joe, there are truly no words to describe how grateful I am for you and your love. From the time of our second first date you captured my heart because you leaned in and listened. It is a gift that I have valued and appreciated for more than twenty years. Because of you, I can see myself. You have encouraged me when I was ready to give up and celebrated with me as I reached each milestone. This simply would not have been possible without you.

To my sons, Jake and Luke, you are my inspiration. I am forever grateful for your love and support. You understood when I brought research to the baseball fields or occasionally missed a game for class or to write. You consoled me when Wally ate my glasses the day before my comprehensive exam. You asked me how things were going and then listened as I went on and on about math. My hope is that you have learned that you can accomplish your biggest dreams through hard work, purpose, and passion and that dreams are always fueled by the love and support of the people around you. You have greatness within you; use it to make the world a better place.

To my parents, Kate and Jim Reeves, who I lost during my first year as a doctoral student. You instilled in me the value of education and gave me every opportunity to soar. You empowered me as a strong, determined woman and simultaneously cultivated a sensitive heart. You were honest and kind and expected the same from your family. Your legacy continues through your three daughters and seven grandchildren who understand the importance of education and living by the golden rule.

To my mom, who had the unique ability of being both a gentle spirit and a dominant force. Although many days you were suffering in silence due to your health, you went to school each day determined to make a difference in the lives of your students. You would be heartbroken by the current dynamics in our world but would also be hopeful because you had a deep belief in the democratic principles that are woven into the fabric of our nation and are reflected in our education system. I keep your pocket version of the U.S. Constitution on my desk. It reflects the identities you held so dearly as a first-generation Irish immigrant, an empowered woman, and a lifelong educator. It is a constant reminder of all that I am and who I intend to become.

To my sisters, Mary Sue Reeves and Ellen Hencken, where do I even begin, you are my everything. Mar, from the time we were little you have been my teacher, I have watched and learned everything about life from you. El, you always agreed to be my student as we played school in the basement for hours, but as we grew up, you also became one of my greatest teachers. To say you have been with me every step of the way would definitely be an understatement. Being your sister is truly one of life's greatest gifts. I love you with all of my heart.

To Joe and Shirley Pavlovich who have loved me like a daughter since the day we met. My late father-in-law Joe immigrated to the United States as a teenager from Croatia in search of a better life. He found that life in Kansas City with my incredibly strong and loving mother-in-law Shirley. Together they raised two compassionate children with quick wits and great laughs, and I am lucky enough to call them family. Big Joe's story represents all that America stands for—the importance of hope and opportunity. Shirley, you have spent a lifetime taking care of everyone around you including me; I'm so fortunate to be the recipient of your love and support.

To my family, Gloria Carson, Matt Carson, Connor Carson, Cailin Carson, Gray Hencken, Molly Hencken, Calvin Hencken, Hope Hencken, Tyler Schimanski, Riley Schimanski, Quinn Schimanski, Barbara O'Brien, Colleen Maguire, Kathleen Ferguson, Bill Ferguson, Maureen Maguire, Mary Ellen Maguire, Bob Crowe, Brian Maguire, Susan Maguire, and Ian Maguire, family is everything. Each of you is woven into my heart in a unique and special way. Thank you for a lifetime of love and support.

To my first lifelong friends, Dr. Jamie Gancayco and Siobhan Haugh. No matter how much time goes by our bond endures. You have always amazed me with your beautiful minds and extraordinary hearts. Because of you, I learned early on what true friendship is all about. Thank you for making room for a third.

To my girls, Angela Bullock, Amy Ellis, Holly George, Wendy Hills, Jeannie Kincaid, Shelly Renaud, and Jenny Shaler, your friendship and love is one of my greatest joys. You have taught me what it means to nurture and grow lifelong relationships. We have laughed together, cried together, and supported each other through life's twists and turns. Although I generally want to go through life wearing a helmet, knowing you are all by my side is a tremendous source of strength and courage for me.

To Amy Smith, you opened my world up to wholeheartedness and true belonging. I knew from our first phone call that we were meant to be marble jar friends. You are wise beyond your years and I deeply cherish our friendship.

To my HMH family, especially Dr. Aimee Corrigan, Brent Hartsell, Mary Jo Casey, Molly Michie, Amanda Dobbins, Kate Gagnon, Susie Benner, Lisa Bush, and Patty Clark, your patience, support, and encouragement through this process have been unbelievable. The work we do is messy and hard, but I am so grateful to get to do it with all of you. Jennifer Lenhardt, your interest, passion, and expertise in this work have been a source of inspiration; I have thoroughly enjoyed and learned from every conversation. Mary Connolly and Mary Jacobsen, thank you for being my math role models. Your leadership and passion have been a gift to me as well as for a countless number of teachers and students. Karen Heiman, you are my role model for hard work, determination, and grit. Jeff Lindmark, thank you for opening the door to this world and letting me tell your stories until I found my own. Amy Scavuzzo, you introduced me to an entire career in education that I had no idea even existed. This was a major turning point in my life, thank you.

To the educators in my life that have shaped my path in ways they might not even be aware of. Mrs. Razkca, my high school Geometry teacher, you dazzled my mind with your overhead and Vis-A-Vis markers but most of all you dazzled my heart by recognizing my mathematical thinking. Flora Wyatt, by including me in the KU PDS program you opened the door to my entire professional life. Karen Parrish, my first coach, mentor, and friend, you made an enormous impact on me, and I miss you terribly. Dr. Barry Cook, my first principal, you taught me the power of instructional leadership and professional learning. I'm forever grateful that you stepped back into my life as my mentor and friend after losing our beloved Karen. Peggy Kooser, you taught me what teaching with passion and purpose was all about. Everything I know about differentiation I learned from you. Kathleen Murphy, your words and wisdom had an enduring impact. I can't tell you how many times during this process I have stopped and thought, Kathleen taught me that. Dr. Debb Oliver, you made me believe I could do this. Dr. Brian McNulty, you are the reason I took the first step to make this happen. The conversation we had in 2013 changed my life.

## Table of Contents

Abstract.....	iii
Acknowledgments .....	iv
Table of Contents .....	vii
List of Figures.....	x
List of Tables .....	xi
Chapter 1: The Research Problem .....	1
Introduction .....	1
Purpose of the Study.....	2
Research Questions .....	3
Statement of the Problem .....	4
Theoretical Framework .....	4
Conclusion.....	11
Chapter 2: Review of the Literature .....	13
Introduction .....	13
Mathematical Identity.....	14
Affective Domain .....	20
The Opportunity Gap.....	28
A High-Quality Curriculum .....	30
Effective Teaching and Learning .....	34
High Expectations .....	41
Conclusion.....	45
Chapter 3: Methodology .....	47

Introduction .....	47
Purpose of the Study .....	48
Research Design .....	48
Research Questions .....	50
Setting .....	50
Participants .....	51
Role of the Researcher .....	52
Data Collection .....	53
Data Organization .....	55
Data Analysis .....	56
Trustworthiness .....	58
Limitations .....	59
Conclusion .....	59
Chapter 4: Participant Results .....	61
Data Organization .....	61
Participant A .....	61
Participant B .....	68
Participant C .....	75
Participant D .....	84
Participant E .....	91
Participant F .....	98
Participant G .....	105
Participant H .....	114



Conclusion.....	122
Chapter 5: Case Results.....	124
Themes .....	124
Conclusion.....	133
Chapter 6: Discussion.....	134
Introduction .....	134
Discussion.....	135
Implications .....	142
Future Research .....	146
Conclusion.....	148
References .....	149
Appendix A .....	170
Appendix B.....	171
Appendix C.....	174
Appendix D .....	175
Appendix E.....	177
Appendix F .....	178

## List of Figures

Figure 1 Model of Multiple Dimensions of Identity (Jones & McEwen, 2000) .....	8
Figure 2 Model for Mathematics Identity (Cribbs et al., 2015) .....	9
Figure 3 Model of Multiple Dimensions of Identity, Adapted (Jones & McEwen, 2000).....	10
Figure 4 Model for Mathematics Identity, Adapted (Cribbs et al., 2015).....	11
Figure 5 Domains of Mathematical Knowledge for Teaching (Ball et al., 2008).....	38
Figure 6 Data Analysis Process, Adapted (Merriam & Tisdell, 2016) .....	58

**List of Tables**

Table 1 Case Categories and Themes.....124

## Chapter 1: The Research Problem

### Introduction

*Principles to Actions: Ensuring Mathematical Success for All* (National Council of Teachers of Mathematics [NCTM], 2014) is framed by six guiding principles for school mathematics, one of which is the principle of access and equity. This principle states that “an excellent mathematics program requires that all students have access to a high-quality mathematics curriculum, effective teaching and learning, high expectations, and the support and resources needed to maximize their learning potential” (NCTM, 2014, p. 59). As noted by Martin (2015), this is not a new principle as it has been included in many previous NCTM documents dating back to 1989. During a plenary session at the 2015 annual NCTM conference, Martin (2015) harshly criticized *Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014). Martin delivered a pointed objection to the access and equity principle stating that “this is a 26-year-old message, couched in a 400-year-old quest for equity in the United States” (Martin, 2015, p. 19). Martin went on to create a compelling, charged argument that the access and equity principle does not go far enough to disrupt the “unspoken, hidden-reality” (Martin, 2015, p. 21) of the oppression that exists. In summary, a singular focus on access to achieve equity is woefully ineffective and insufficient.

In reaction to Martin’s comments, the leadership of NCTM published a response calling for “mathematics education colleagues and stakeholders to collaboratively engage with NCTM” in productive conversations related to access and equity (Briars, Larson, Strutchens, & Barnes, 2015, p. 1). The formal response by NCTM acknowledged many shortcomings and expressed a commitment to providing the courageous leadership necessary for this type of monumental change (Briars et al., 2015). As a result, “the NCTM board officially reframed its equity work to

focus on access, equity, and empowerment to capture the crucial constructs of students' mathematical identities, sense of agency, and social justice" (Larson, 2016, para. 5). In addition, the National Council of Supervisors of Mathematics (NCSM) and TODOS: Mathematics for ALL released a joint position statement, *Mathematics Education Through the Lens of Social Justice: Acknowledgments, Actions, and Accountability* (2016) in an effort to "transform its vision and actions" (Larson, 2016, para. 5). The first step in taking an equity stance in mathematics is for researchers and practitioners to acknowledge and "reflect on privileges and obstacles in their own mathematics histories" (NCSM & TODOS, 2016, p. 3). "These stories help to provide an understanding of how teachers' identities as mathematics learners shape their mathematics teacher identities and how these mathematics teacher identities, in turn, influence the decisions and actions enacted in the mathematics classroom" (Aguirre, Mayfield-Ingram, & Martin, 2013, p. 28). NCTM (2018) calls for a focus on developing positive mathematical identities in the daily work of teaching and learning mathematics; therefore, developing a robust understanding of the complex notion of mathematical identity must be a priority for scholars in pursuit of advancing equity in the mathematics classroom.

### **Purpose of the Study**

The purpose of this study was to develop an understanding of the mathematical identity of elementary preservice teachers and to explore their perceptions of equity. In particular, this study focused on understanding how the affective domain "emerges in the forefront of identity formation" (Frade & Meira, 2010, p. 262). The affective domain includes beliefs about recognition, beliefs about mathematics, emotions related to mathematics, and beliefs about an individual's mathematical competence and performance. The critical sociocultural experiences of preservice teachers, a theoretical underpinning of this study, were also examined to further

understand the formation of a mathematical identity. Finally, this study explored preservice teachers' perceptions of equity and how these perceptions influenced their mathematical identities. This study aimed to make a practical contribution to the understanding of mathematical identity for those who support the development and growth of both preservice and inservice teachers.

### **Research Questions**

The research questions for this study were determined through an iterative process with the goal of creating alignment and cohesiveness between the critical elements of qualitative research. Honoring the inductive nature of qualitative research, this study began with a broad central question supported by subquestions with the understanding that the final questions would emerge through the research process. According to Creswell and Poth (2018), the researcher “explores the data and only after some time formulates more precise research questions” (p. 343).

Central research question: How are the mathematical identities of preservice teachers shaped?

1. How do beliefs about mathematics competence and performance develop and how do they shape the mathematical identity of preservice teachers?
2. How do beliefs about recognition develop and how do they shape the mathematical identity of preservice teachers?
3. How does interest in mathematics develop and how does that shape the mathematical identity of preservice teachers?
4. How do perceptions of equity develop and how do they shape the mathematical identity of preservice teachers?

### **Statement of the Problem**

Empowering the next generation of mathematical thinkers, through equity-based practices, is dependent on a student's access to a high-quality curriculum, effective teaching and learning, and high expectations, all of which are mediated and filtered by the mathematical identity of the teacher (Drake, Spillane, & Hufferd-Ackles, 2001; Frade, Roesken, & Hannula, 2010; Heyd-Metzuyanim, Lutovac, & Kaasila, 2016; Ma & Singer-Gabella, 2011; Spillane, 2000). Currently, many future elementary teachers begin teacher preparation programs with developing mathematics knowledge for teaching (Ball, Thames, & Phelps, 2008) as well as with a fragile mathematical identity (Ball & Forzani, 2010; Ball, Hill, & Bass, 2005; Hodgen & Askew, 2007; Lui & Bonner, 2016; Ma, 1999/2010). Consequently, "an enduring problem in mathematics education is its task to build both mathematics and teaching identities" (Adler, Ball, Krainer, Lin, & Novotna, 2005, p. 378). Additionally, in order for teachers to productively contribute to the formation of their students' mathematical identities, they must themselves have well-developed mathematical identities (Grootenboer & Zevenbergen, 2008, p. 246). Therefore, an intentional focus on understanding and improving the mathematical identity of preservice teachers is critical as we aim to empower each and every student through mathematics.

### **Theoretical Framework**

The notion of teacher identity can be situated within many theoretical frames. For the purpose of this study, identity was considered through both sociocultural and narrative theories. Grootenboer and Zevenbergen (2008) suggest that a "plurality of theoretical lenses may indeed provide a richer and more comprehensive understanding of the issues of identity in mathematics education" (p. 243). To create unity between these two theories, the definition of mathematical identity must reflect both. In this study, a mathematical identity is viewed as both a process and

product (Beauchamp & Thomas, 2009). Mathematical identity is one of the many interrelated identities of an individual (Jones & McEwen, 2000). A mathematical identity is situated, dynamic, and socially constructed (Boaler, William, & Zevenbergen, 2000). A mathematical identity is one's knowledge, beliefs, attitudes, and emotions (Lotovac & Kaasila, 2013). Mathematical identity includes cognitive dimensions, affective qualities, and life histories (Grootenboer & Zevenbergen, 2008). Mathematical identity "can emerge in the form of stories that announce to the world who we think we are, who we want to become, and who we are not" (Aguirre et al., 2013, p. 14). Life histories, described narratively, provide both a window and mirror for understanding mathematical identity (Drake et al., 2001). Collectively, the previous statements define mathematical identity and represent the essence of both sociocultural and narrative theories.

Narrative theories are typically associated with the work of Jerome Bruner, a 20th century American psychologist. Bruner (1987/2004) has two primary theses: (1) narrative provides a structure for describing lived time; (2) there is a reciprocal relationship between life and narrative. Bruner expands on his second thesis arguing that (1987/2004):

Eventually the culturally shaped cognitive and linguistic processes that guide the self-telling of life narratives achieve the power to structure perceptual experience, to organize memory, to segment and purpose-build the very "events" of life. In the end we become the autobiographical narratives by which we "tell about" our lives. (p. 694)

Therefore, creating a mathematical autobiography is considered identity work and underscores the notion that identity is both a process and product (Lotovac & Kaasila, 2013). A critical aspect of the narrative process is how an individual positions herself as the protagonist in the story, as well as how the individual organizes the plot by relating actions and events (Kaasila, 2007).



From an analytical perspective, it is important to note that the narrator tends to adjust the narrative based on the audience (Kaasila, 2007). Goodson and Sikes (2001) state that “a mathematical autobiography provides evidence to show how individuals negotiate their identities and consequently, experience, create, and make sense of the rules and roles of the social worlds in which they live” (as cited in Latterell & Wilson, 2016, p. 279). In particular, narratives play a critical role in the sociocultural context of teacher preparation programs as preservice teachers negotiate the relationship between their mathematical identity and their teacher identity (Kaasila, 2007).

Sociocultural learning theory can be traced back to the 1900s and is attributed to the work of Soviet psychologist Lev Vygotsky (Nasir & Hand, 2006). Vygotsky believed that “all people had the right, and a potential for, developing higher order thinking that they would not have access to except through attending school” (Young & Muller, 2013, p. 235). Therefore, school provides one context for which complex social and cultural exchanges facilitate and advance learning (Young & Muller, 2013). Over the last several decades, there has been a social turn in mathematics research, which has transformed sociocultural learning theories from a central focus on cultural psychology and cognition to include the constructs of identity and social interactions (Gutiérrez, 2013; Nasir & Hand, 2006). This shift includes understanding the interrelated nature of race, culture, gender, socioeconomics, power, and identity and provides theoretical tools for those committed to equity in mathematics (Gutiérrez, 2013).

According to Nasir and Hand (2006), one aspect of sociocultural learning theory includes a shift in relationships within a social context. This is particularly relevant to this study, as it directly relates to identity formation and reformation (Nasir & Hand, 2006). Nasir and Hand (2006), suggest that “as individuals come to participate in a cultural practice, they negotiate an

identity that is part what they have come to view as consistent about themselves in their lives, part what they perceive to be available to them in a practice, and part how they are perceived by social others” (Nasir & Hand, 2006, p. 467). Because the notion of identity is so complex, this statement can be easily misinterpreted as a unitary perspective of identity, suggesting that identity is the sum of the parts. However, “identity is the weaving together of complex selves in relation to available discourse and to the complex selves of others” (Walshaw, 2013, p. 110). The Model of Multiple Dimensions of Identity, a research-based conceptual model developed by Jones and McEwen (2000), makes the abstract construct of complex selves comprehensible.

Building on the existing research of multiple identities, Jones and McEwen (2000) conducted a grounded research study to examine undergraduate students’ “understanding of their own identity and experiences of difference and the influence of multiple dimensions of identity on an evolving sense of self” (Jones & McEwen, 2000, p. 407). The result of this study was the development of the Model of Multiple Dimensions of Identity (Figure 1). This illustrative model is intended to communicate how contextual influences situate the multiple identities of an individual at a particular moment in time (Jones & McEwen, 2000). At the center of this model (Figure 1) is the core identity of the individual. The core identity is described as the “personal identity, somewhat protected from view” (Jones & McEwen, 2000, p. 408). This may also be described as a person’s essence or core sense of self. The core identity is surrounded by the more externally defined dimensions such as gender, race, culture, socioeconomic status, and so on (Jones & McEwen, 2000), together making up the multiple interrelated identities of an individual. In Figure 1, the distance of the dots of the externally defined dimensions from the core self is relative to the salience of the dimensions to this particular person (Jones & McEwen, 2000). Finally, the outside circle represents the “the context within which the individual

experiences multiple dimensions of identity . . . and includes both the core and intersecting identity dimensions” (Jones & McEwen, 2000, p. 410). This conceptual model provides a framework for understanding the interrelated nature of multiple identities that is essential to understanding mathematical identity. However, it is not specific to mathematics, and therefore it is beneficial to consider it in conjunction with the model for mathematics identity developed by Cribbs, Hazari, Sonnert, and Sadler (2015).

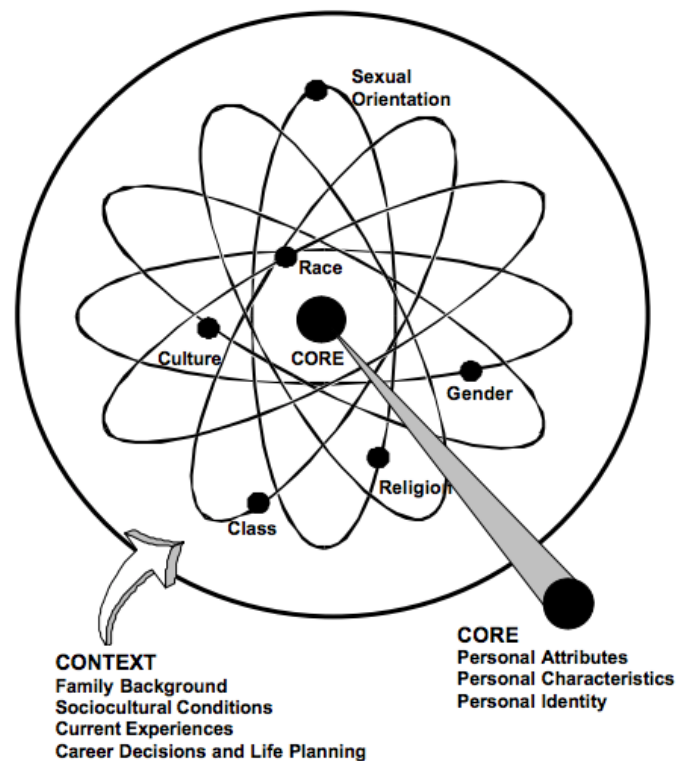


Figure 1 Model of Multiple Dimensions of Identity (Jones & McEwen, 2000)

Cribbs et al. (2015) empirically tested a previously developed model of science identity, and based on the results of the study, the researchers reconceptualized a model for mathematics identity (Figure 2). As illustrated in Figure 2, competence and performance have an indirect effect on a mathematics identity whereas recognition and interest have a direct effect (Cribbs et

al., 2015). These findings are significant because they suggest that “performance and competence self-perceptions are not sufficient to developing a mathematics identity—recognition and interest are paramount” (Cribbs et al., 2015, p. 1059). Moreover, recognition has the greatest impact on mathematics identity, thus highlighting the critical role of teachers in the development of a positive mathematical identity through an equity lens (Cribbs et al., 2015). The descriptions of these two models provide a rich understanding of the complex notion of mathematical identity; however, it is necessary to discuss how they are related to have a more complete understanding.

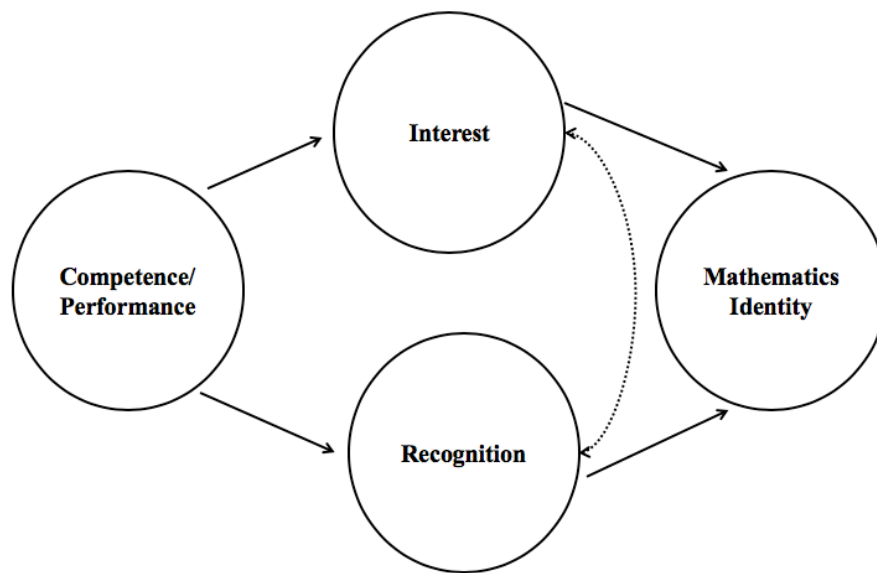


Figure 2 Model for Mathematics Identity (Cribbs et al., 2015)

In both models, mathematics identity, referred to as mathematical identity in this study, and core identity are both described as an enduring sense of self (Cribbs et al., 2015; Jones & McEwen, 2000). It is then logical to represent mathematical identity and the core identity as concentric circles with the core identity being the innermost circle within each model (Figures 3 and 4). Together the integrated models represent mathematical identity within a complex system

that accounts for the multiple dimensions of a learner's selves, the interplay within a sociocultural context, and the dynamic process of identity formation. Through this perspective of identity and identity formation, the ontological and epistemological assumptions of sociocultural and narrative theories emerge as the nature of reality (ontology) suggests that the process of becoming is interdependent with one's knowledge of self (epistemology), and in relationship with a dynamic community of practice (Packer & Goicoechea, 2000). The community of practice then becomes the primary means for the enactment of the mathematical identity. Additionally, mathematical identity is manifested and shaped through the life stories an individual tells about their experiences and relationship with the mathematics community of practice (Kaasila, 2007; Lutovac & Kaasila, 2012). An integrated model of mathematical identity and the harmonious unification of both sociocultural and narrative theories create the framework for this study.

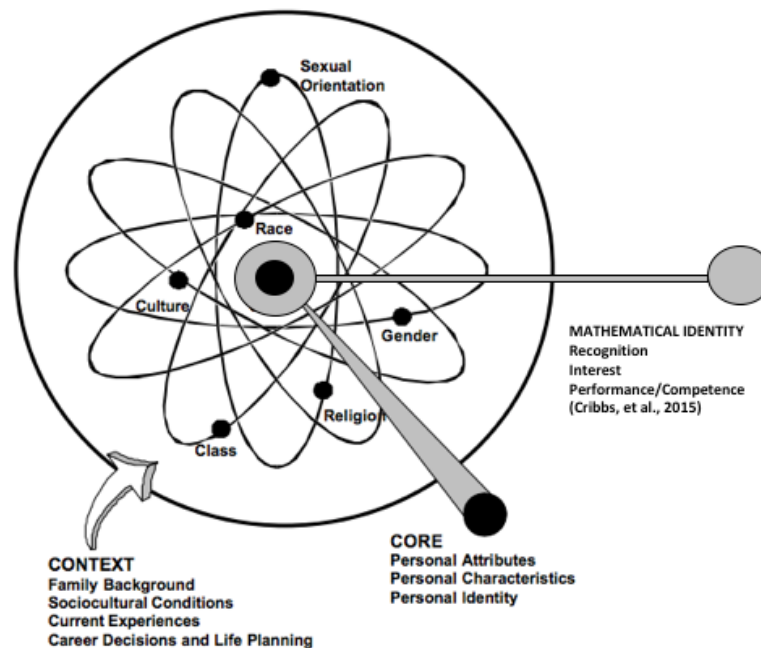


Figure 3 Model of Multiple Dimensions of Identity, Adapted (Jones & McEwen, 2000)

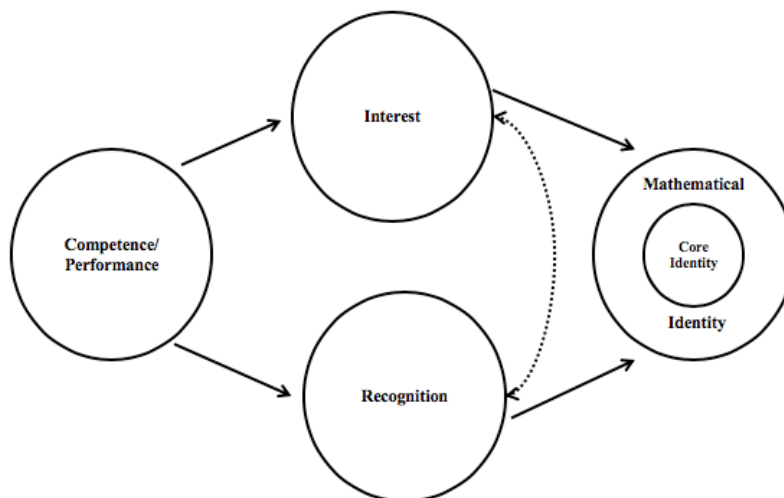


Figure 4 Model for Mathematics Identity, Adapted (Cribbs et al., 2015)

## Conclusion

Mathematics has a long history of creating privilege and status within a sociocultural context (Gutiérrez, 2013). Guided by the Access, Equity, and Empowerment Principle (NCTM 2014; NCSM & TODOS, 2016), scholars and practitioners are engaged in efforts to address these issues. Embedded within the focus of empowerment is the construct of mathematical identity. A well-developed mathematical identity, in addition to developing conceptual understanding and procedural fluency, is critical to “ensuring mathematical success for all” (NCTM, 2014). Efforts to productively develop the mathematical identity of students must begin by addressing the mathematical identity of teachers. Teacher preparation programs provide a forum for identity work, especially within an elementary preservice setting. Clandinin and Connelly (2000) state that “preservice teachers’ development of professional knowledge and practice are deeply entwined . . . with their identities” (as cited in Lutovac & Kaasila, 2011, p. 227), thus creating a complex challenge for those who prepare future elementary mathematics educators. A similar challenge exists when considering the mathematical identity of practicing

teachers. However, the potential benefits of reframing the learning experiences for both preservice and inservice teachers based on a deeper understanding of mathematical identity made this study a worthy endeavor.

## Chapter 2: Review of the Literature

### Introduction

Mathematical identity is currently claiming the research spotlight in the quest to understand effective mathematics teaching and learning that provides access and equity to empower each and every student. This current context-specific focus of identity research has emerged over the last two decades and is rooted in identity research within psychology, sociology, and anthropology (Beauchamp & Thomas, 2009; Darragh, 2016; Grootenboer & Zevenbergen, 2008). In the early 2000s, mathematics researchers made the “identity turn” (Darragh, 2016, p. 22) and began to grapple with this notion. A review of the early literature suggests the term *mathematical identity* was not widely used. Forester (2000) conducted a study that utilized the term *mathematical identity* but also used it synonymously with *self-concept*. Most contemporary scholars include self-concept as an element of mathematical identity but would not consider it a synonym (Beauchamp & Thomas, 2009). Other researchers during this time began to consider learner identity in the context of mathematics, therefore creating the foundation for currently held understandings of mathematical identity (Boaler, 2002; Drake et al., 2001). Additionally, many of these early studies began exploring mathematical identity through a sociocultural lens which has carried through to the present day.

For those who frame mathematics learning through a sociocultural perspective, identity is considered the “missing link” to deconstructing, analyzing, and understanding this complex phenomenon (Darragh, 2016; Sfard & Prusak, 2005). Sfard and Prusak (2005) provide an emancipatory message related to identity in which they state that with “the acceptance of identity as the pivotal notion of the new research discourse comes the declaration that human beings are active agents who play decisive roles in determining the dynamics of social life and in shaping



individual activities” (p. 15). Fundamental to this message about mathematical identity is a sense of agency within a transformative process of becoming mathematical (Beauchamp & Thomas, 2009). Effective teachers must be transformative agents of their own mathematical identity as they mediate the sociocultural learning experiences within a classroom that influence the mathematical identity of their students (Frade et al., 2010).

### **Mathematical Identity**

Mathematical identity is at the center of this study; therefore, a thorough review of the research was necessary to gain an understanding of both the empirical and theoretical scholarship related to this line of research. Scholars from different disciplines, applying different theoretical frameworks, have zoomed in on the individual or have used a wide-angle lens to gain a sense of the context and those interacting within it (Darragh, 2016). In a review of the literature, Darragh (2016) examined 188 articles related to mathematical identity that were published in scholarly journals from 1997 through 2014. The majority of articles were qualitative case studies with fewer than 10 participants (Darragh, 2016). Half of the articles focused on the mathematical identity of kindergarten through undergraduate students (Darragh, 2016). “Studies focusing on teachers (28%) and pre-service teachers (17%) looked either at the professional identity of mathematics teachers or at the mathematical identity of teachers in general” (Darragh, 2016, p. 23). Of the 188 articles, 57 addressed externally defined dimensions of identity such as gender, race, ethnicity, and socioeconomic status (Darragh, 2016). These 57 articles included issues related to equity which “suggests that identity research is indeed a vehicle in which some mathematics educators investigate students’ experience of marginalization of schooling” (Darragh, 2014, p. 23). Although there are many different approaches to foregrounding identity, “they all share a common thread—the notion that within the practice of mathematics teaching

and learning, the people within the practice, and the social conditions they experience, play a major role (Grootenboer, Smith, & Lowrie, 2006, p. 614).

Boaler and colleagues are amongst the pioneers of the early research on mathematical identity and have built upon this work for almost two decades. Boaler (1998, 1999) began by framing her work within a situated perspective, drawing on the research of Lave (1988). Boaler's (1998) three-year ethnographic case study of two schools in the UK focused on students age 13 to 16. Each school had different approaches to mathematics; "Amber Hill" was considered to be traditional, whereas "Phoenix Park" was reform oriented (Boaler, 1998, 1999). Boaler (1998, 1999) examined the particular constraints and affordances of each learning environment in an effort to go beyond the learning transfer theories popular during this time in order to "cross the social-psychological divide, providing a means to understand the actions of students, as active agents who develop their own beliefs and practices that are nevertheless shaped by the communities in which they engage" (p. 279). Boaler concluded that the different constraints and affordances within the different environments shaped the students' beliefs about mathematics. Amber Hill students came to believe that "mathematics was all about memorizing a vast number of rules, formulas, and equations" (Boaler, 1998, p. 46). In contrast, the Phoenix Park students "had the belief that mathematics involved active and flexible thought (Boaler, 1998, p. 57). The notion of mathematical identity was not fully developed in this study; however, Boaler went on to expand on these findings in later studies in which mathematical identity was a primary focus.

In a study conducted by Boaler and Greeno (2000), the researchers interviewed 48 advanced placement (AP) calculus students from six different schools to develop an understanding of their figured worlds of mathematics learning and the impact of that on their

identity. Of the 48 students, 16 students in the same two classrooms described their figured worlds as social, cooperative, and discussion-based. The remaining 32 students, in the other four classrooms, portrayed their figured worlds as traditional, individualistic, didactic, and highly ritualized (Boaler & Greeno, 2000). Although the students self-selected this AP mathematics course, which one might assume would align to a positive mathematical identity, “17 of the 48 students reported that they hated or disliked mathematics, 16 of these students were taught in the traditional classes” (Boaler & Greeno, 2000, p. 190). The researchers suggested that these students rejected a future-oriented mathematical identity because the practices within the traditional classroom conflicted with their need to be “creative, divergent thinkers” (Boaler & Greeno, 2000, p. 190). Building upon the data from this study, Boaler et al. (2000) interviewed 72 additional students in six schools in the UK to further understand how students “construct a sense of themselves in relation to mathematics” (p. 6). The researchers’ findings suggest that students want to be successful in mathematics but do not see themselves as mathematicians or as individuals who belong to a mathematics community of practice. This notion of belonging is particularly interesting in the context of access and equity.

Within a sociocultural framework, belonging to a community of practice is a fundamental tenet. “Participation in this sense is both personal and social. It is a complex process that combines doing, talking, thinking, feeling, and belonging. It involves our whole person, including our bodies, minds, emotions, and social relations” (Wenger, 1998, p. 56). Belonging was one of the primary themes that emerged through a case study focused on identity construction and the mathematics learning experiences of students as they transition to high school (Darragh, 2013). Radovic, Black, Salas, and Williams (2017) explored the relationships of peer groups and the impact on mathematical identity, and how belonging to certain groups

“mediated” girls’ identification with mathematics by examining how these relationships were used to maintain or negotiate different positions of success (Radovic et al., 2017, p. 437). The researchers conducted a nested case study of three female students, ages 13–14, with high achievement levels and positive relationships with mathematics (Radovic et al., 2017). Each was in the same mathematics classroom but belonged to a different peer group, describing the unique tensions in managing their positive mathematical identity. The researchers concluded that the different peer group that each participant belonged to was influential in mediating their mathematical identity (Radovic et al., 2017). Furthermore, the researchers highlighted how a female gender identity contributed to the participants’ mathematical identity, as one participant did not see how mathematics would align to her future gender-oriented identity. Additionally, the researchers noted that the participants associated mathematics as being a “male domain” where males have a natural ability (Radovic et al., 2017). This belief created a tension between their mathematical identity and their gender identity (Radovic et al., 2017). This finding is important as researchers consider how students negotiate and reconcile their various identities within a mathematics community of practice.

Good, Rattan, and Dweck (2012) echo these findings, stating that a sense of belonging to mathematics is a factor in the underrepresentation of females in mathematics. The researchers also state that this factor extends to the representation gap of African American and Latinx students who also struggle to belong in mathematics (Radovic et al., 2017). Because the overwhelming majority of elementary educators are White females, they must be keenly aware of the tensions associated with belonging as it relates to their gender and racial identities. This may prohibit or provide a sense of belonging for their students as teachers negotiate their own gender and racial identities within a mathematics community of practice. An example of this can

be found in the autobiography of a female second-grade teacher in which she states: “I am very cognizant of getting all my kids involved in a lesson, making sure that the girls as well as the boys are not only getting it, but are having fun wrapping their brains around the puzzle of solving a problem” (Gujarati, 2013, p. 641).

Gujarati (2013) provides hope for breaking the cycle of perpetuating the unproductive mathematical identities teachers bring with them to the classroom from their experiences as students. Through a qualitative case study, Gujarati (2013) examined the mathematical identity and practices of three female second-grade teachers who were early in their careers. The findings of this study suggest that for all three teachers there was an inverse relationship between their negative previous experiences with mathematics and their current teaching practices (Gujarati, 2013). A negative mathematical identity “does not have to be a life sentence for perpetuating negative experience in students or negative dispositions if teachers are willing to reflect open and honestly on their beliefs and practices and want to change” (Gujarati, 2013, p. 645). Motivation to engage in reflective practices to improve their relationship with mathematics and to effectively implement reform-based practices is attributed to accountability (Gujarati, 2013). All three teachers cited reasons associated with school-based data and assessment practices as a motivating factor (Gujarati, 2013). Gujarati (2013) suggests that teachers should engage in reflective practices, such as creating mathematics autobiographies, as a means to examine how their own histories influence their practice.

In addition to writing mathematics autobiographies, engaging teachers in metaphoric writing exercises also provides insight into their mathematical identity. Latterell and Wilson (2017) utilized this strategy to compare the mathematics metaphors created by elementary preservice teachers and secondary preservice teachers. Through the analysis of the elementary

preservice teachers' metaphors, the researchers identified two primary themes. "First, 43% of the metaphors were categorized as viewing mathematics as an up and down process that the students felt little or no control over. Second, 25% of the metaphors described mathematics as being very difficult and unpleasant" (Latterell & Wilson, 2017, p. 52). The secondary preservice teachers also viewed mathematics as a process but as a cognitive process rather than an emotional process (Latterell & Wilson, 2017). Their metaphors suggested that mathematics is not easy, but there is a sense of success within the challenges it presents. The final theme that emerged from the secondary preservice teachers' metaphors was that mathematics is essential—essential to solve real-world problems but also essential because it provides a sense of wonder and beauty in the world (Latterell & Wilson, 2017). The differences between the two groups was so stark that the researchers were able to blindly sort the metaphors by group with 100% accuracy (Latterell & Wilson, 2017). These stark differences were also present as the researchers analyzed the mathematical identities of the teachers through the metaphors. They concluded that secondary teachers see themselves as active doers of mathematics whereas the elementary preservice teachers "do not identify themselves as doing mathematics, but as having mathematics done to them, and thus being an outsider in the process" (Latterell & Wilson, 2017, p. 36). This finding connects to the Boaler and Greeno (2000) study in which they found that students tended to reject a future-oriented mathematical identity because traditional mathematics practices communicated a message that they were passive receivers of knowledge.

Conversely, in a study conducted by Jong (2016), the researcher examined how reform-oriented experiences positively impacted the mathematical identity of a novice elementary teacher. Through this three-year phenomenological case study, three themes emerged as influential to a productive mathematical identity: "(a) influential mathematics education models,

(b) commitment to learning, and (c) school related factors” (Jong, 2016, p. 302). Of particular interest is the past experiences with mathematics that the participants shared that included reform-based practices to develop deep conceptual understanding in conjunction with high expectations for learning (Jong, 2016). The participant was intent on replicating these practices for her students, thus “developing a clear teaching identity early on” (Jong, 2016, p. 303). Although the participant had a productive mathematical identity as a foundation, transitioning to the complex work of teaching mathematics was still challenging and required support (Jong, 2016). According to Jong (2016), “teacher education programs need to explicitly address the construction and in some cases deconstruction, of teaching identities . . . if reform-oriented methods are the goal” (p. 308).

Many studies have examined the construction of a mathematical identity with various purposes. Throughout the literature there are common threads that suggest mathematical identity is developed and formed through lived experiences; it is through examining these lived experiences that the most basic human affective needs emerge—agency and belonging. Darragh (2016) notes that in some studies identity has become a “catch-all term for affect” (p. 28) and cautions researchers not to rebrand the affective domain as identity. This study acknowledges that mathematical identity is a complex construct that includes both cognitive and affective elements; however, this study will concentrate on the affective domain.

### **Affective Domain**

As the notion that learning mathematics is not purely cognitive gained acceptance, social psychologists began studying the influence of affect in mathematics (Di Martino, 2016; McLeod, 1992). Many scholars who study the affective domain include the constructs of beliefs, attitudes, and emotions, although there are no universally agreed upon definitions and conceptual models.

Beliefs are generally more cognitive and stable, and are developed over time (McLeod, 1992). According to McLeod (1992) beliefs can be categorized by beliefs about mathematics, beliefs about self, beliefs about mathematics teaching, and beliefs about the social context. Emotions are an elusive construct as “all emotions are considered affective but not all affective conditions are emotions” (Ortony, Clore, & Foss, 1987, p. 343). However, there is some agreement that through classical conditioning emotions experienced repeatedly over time develop into attitudes (Ayob & Yasin, 2017). Within McLeod’s affective framework (1992), beliefs, attitudes, and emotions are considered siblings. However, other scholars consider attitudes to be the bridge between beliefs and emotions (Di Martino & Zan, 2010; 2011; Liljedahl & Hannula, 2016). Noted throughout the contemporary literature on affect are varying perspectives about the nature of beliefs, attitudes, and emotions as well as the relationship between them.

Although many scholars have studied beliefs, a singular definition does not exist (Gujarati, 2010; Maasepp & Bobis, 2015; Philipp 2007; Richardson, 1996). Still, there are many common threads which can be woven together to create a working scheme around beliefs. Beliefs are generally created through years of experiences (Clark et al., 2014; McLeod, 1992; Raymond, 1997; Thompson, 1984), are typically stable, and somewhat resistant to change (Philipp, 2007). Ernest (1989) refers to a “system of beliefs, conceptions, values, and ideology” (p. 19). Richardson (1996) synthesizes the work of anthropologists, social psychologists, and philosophers and suggests beliefs are “psychologically held understandings, premises, or propositions about the world that are thought to be true” (p. 104). Philipp (2007) builds upon Richardson’s work and states, “beliefs might be thought of as lenses that affect one’s view of some aspect of the world or as dispositions toward action” (p. 259). Schoenfeld (1999) describes beliefs as an individual’s understanding that influences the way s/he conceptualizes mathematics.



Although there are differences among the definitions, there is a general consensus that beliefs clearly filter understanding, influence practice, and impact mathematical identity.

Mathematics scholars have noted that beliefs about mathematics are integral to the formation of a mathematical identity (Boaler, 1998, 1999; Boaler & Greeno, 2000; Boaler et al., 2000; Boaler & Selling, 2017). To examine beliefs about mathematics, it is helpful to organize and describe similarly held beliefs. Ernest (1989) developed a model of mathematics beliefs that identified three categories: the instrumentalist, the Platonist, and problem-solving. The instrumentalist views mathematics as a “useful but unrelated collection of facts, rules, and skills” (Ernest, 1989, p. 20). This view is contrary to the widely held belief of many scholars around the importance of coherent learning progressions (Clements & Sarama, 2011; Daro, McCallum, & Zimba, 2012). The Platonist believes mathematics is a “static but unified body of knowledge, consisting of interconnecting structures and truths” (Ernest, 1989, p. 20), in which a teacher would guide the discovery of the “correct” method. On a continuum, the Platonist views are between the instrumentalist and problem-solving (Philipp, 2007). Finally, the problem-solving view suggests that mathematics is a “continually expanding field of human inquiry” (Ernest, 1989, p. 20), in which students discover methods and engage in reasoning and discourse to make sense of mathematics (Clark et al., 2014). Those who hold this belief tend to have a student-centered or constructivist approach to mathematics (Clements & Battista, 1990; Ernest, 1989; Kutaka et al., 2016; Thompson, 1984). Adopting a problem-solving view is the focus of improvement efforts in mathematics practice and also has implications for identity development as it relates to interest in mathematics (Boaler, 1998, 1999; Boaler & Greeno, 2000; Boaler & Selling, 2017; Boaler et al., 2000).

Just as beliefs about mathematics impact identity, beliefs about intelligence do as well (Rattan et al., 2012). Although implicit theories of intelligence (Rattan et al., 2012) are not directly related to Ernest's model of mathematics (1989), connections can be made. The implicit theories of intelligence are beliefs about "the way an individual conceives of intelligence" (Murphy & Dweck, 2010, p. 284). This includes the entity theory (Murphy & Dweck, 2010; Rattan et al., 2012), a belief that intelligence is fixed, much like the static nature of mathematics within the Platonist's beliefs (Ernest, 1998). In juxtaposition to the entity theory, but in alignment with the problem-solving view, is the incremental theory of intelligence. This belief of intelligence suggests that intelligence is flexible and expandable, similar to the expanding nature of mathematics in the problem-solving view (Murphy & Dweck, 2010; Rattan et al., 2012). Rattan et al. (2012) found that teachers who hold an entity theory of intelligence tended to diagnose a student's low ability after a single poor performance, thus engaged in "comforting feedback" based on this assumption. Students who received this type of feedback reported lower motivation and decreased expectations of themselves (Rattan et al., 2012). Beliefs about intelligence are directly related to beliefs about competence and performance. As we strive for "systemic excellence" (NCTM, 2014, p. 3), changing beliefs about mathematics and intelligence should be of primary importance. Both beliefs and attitudes encompass aspects of cognition and are influenced by emotions (Philipp, 2007).

Mathematics is widely known to be an emotionally charged experience for many students and teachers, therefore it is important to examine the emotions related to mathematics as they "bias attention and memory and activate action tendencies" (Di Martino & Zan, 2011). To define *emotions*, it is helpful to draw on the scholarship of psychology. Within the field of psychology, Ortony et al. (1987) cited a need for a taxonomy for the affective lexicon to better articulate what

emotion is. The taxonomy is meant to differentiate words within the broader affective domain, as many words were miscategorized as emotions in the research. The authors suggest this confusion stems from emotion and nonemotion distinctions that are vague and arbitrary. According to Ortony et al. (1987), “the best examples of emotions fall into any of the three categories of mental conditions for which affect is focal— affective states, affective-cognitive conditions, affective-behavioral conditions” (p. 358). Emotion words can be distilled into a basic-level categorization such as love, joy, anger, sadness, and fear and then sorted as either positive or negative (Shaver, Schwartz, Kirson, & O’Connor, 1987).

Negative emotions, especially anxiety, are well documented in mathematics research and have been found to be a barrier to mathematics achievement (Beilock, Gunderson, Ramirez, & Levine, 2010). A Google Scholar search for “mathematics anxiety” returned 452,000 results with 3,900 being from the first three months in 2019. Mathematics anxiety is the feeling of uneasiness when faced with a mathematical task in the classroom or through everyday experiences (Lake & Kelly, 2014; Ramirez, Hooper, Kersting, Ferguson, & Yeager, 2018). For some, mathematics anxiety can be so intense that it evokes a physiological reaction (Stoehr, 2017). According to Lake and Kelly (2014), “an extremely high number of elementary teachers experience substantial levels of math anxiety” (p. 263). Furthermore, when female elementary teachers are anxious about mathematics, research shows that this has a negative impact on female students while boys are resistant to this transfer (Beilock et al., 2014). This is cause for great concern as it is “influencing girls’ gender-related beliefs about who is good at math” (Beilock et al., 2014, p. 1862). Mathematics anxiety is categorized under the basic-level emotion labeled *fear*, and although this a critical focus for research, it is also important to consider positive emotions related to mathematics.

On the opposite end of the emotional spectrum is joy. In one of the four key recommendations for catalyzing change in mathematics, NCTM (2018) states that “each and every student should learn the essential concepts in order to expand professional opportunities, understand and critique the world, and experience joy, wonder, and beauty in mathematics” (p. 7). Mathematics research related to joy is limited, therefore unpacking this emotion must rely on the research within positive psychology. Positive psychology focuses on the “positive features of human existence that make life worth living” (Donaldson, Dollwet, & Rao, 2015, p. 185). Even within positive psychology, “joy appears to be the least studied of the positive emotions” (Watkins, Emmons, Greaves, & Bell, 2017, p. 1) despite being associated with human flourishing. According to Watkins et al. (2017) joy provides a sense of freedom and timelessness. “Joy is relational both in its appraisal and in its function. We experience joy when we appraise a situation as indicating increased connection with something good” (p. 3). Joy can also be experienced through triumph and challenge (Watkins et al., 2017). Furthermore, joy has an enduring effect as it “broaden(s) people’s momentary thought-action repertoires . . . these thought-action repertoires build intellectual, social, and psychological resources for the future” (Fredrickson, 2003, p. 333). Experiencing the wonder and beauty of mathematics most certainly creates a sense of joy and promotes both an interest in mathematics and a positive attitude towards mathematics.

Consistent with the other constructs within the affective domain, the definition of *attitude* varies. According to Philipp (2007), attitudes are “manners of acting, feeling, or thinking that show one’s disposition or opinion” (p. 259). Although it may be common to categorize attitudes as positive or negative, especially related to mathematics, researchers provide caution about this type of generalization (Di Martino & Zan, 2010). Labeling an attitude towards mathematics as

negative without examining the associated beliefs and emotions is ineffective and insufficient if the goal is to understand attitudes in an effort to improve mathematics achievement (Di Martino & Zan, 2010). To provide theoretical tools and clarity within mathematics affective research and mathematics teaching practices, Di Martino and Zan (2010) conducted a ground theory study which led to the development of the three-dimensional model for attitude (TMA). Through the analysis of 1,662 mathematics autobiographies of students ranging from first grade through high school, the three dimensions of attitude emerged: emotional disposition, vision of mathematics, and perceived competence (Di Martino & Zan, 2010). This model maintains that attitude is an amalgamation of emotions and beliefs. Although the researchers situate this model under the construct of attitude, parallels can be made between the TMA and the model for mathematics identity developed by Cribbs et al. (2015).

Both the model of mathematics identity (Cribbs et al., 2015) and the TMA (Di Martino & Zan, 2011) include beliefs about competence. “Competence is defined as the students’ beliefs about their ability to understand mathematics” (Cribbs et al., 2015, p. 1051). Additionally, the model for mathematics identity addresses beliefs about an ability to perform in mathematics (Cribbs et al., 2015). Embedded within beliefs about performance is the notion of agency. In this sense, mathematics agency refers to how students are empowered and “positioned to take initiative in constructing meaning and understanding” (Gresalfi, Martin, Hand, & Shuo, 2009, p. 56). This intersects with beliefs about mathematics and ultimately opportunities and access to equitable mathematics learning experiences. Interest (Cribbs et al., 2015) encompasses both beliefs about mathematics and emotional disposition (Di Martino & Zan, 2011). Cribbs et al. (2015) define interest as “the desire or curiosity to learn mathematics” (p. 1052). “People feel interest, for instance, when they encounter something that is mysterious or challenging, yet not

overwhelming. Interest creates the urge to explore, to learn, to immerse oneself in the novelty and thereby expand the self (Fredrickson, 2013, p. 4). A primary distinction between these two models is the absence of recognition within the TMA—a critical consideration when examining mathematical identity.

*Recognition* is defined as “how students perceives others to view them in relation to mathematics” (Cribbs et al., 2015, p. 1052), once again underscoring the power of the sociocultural context. These perceptions develop through the explicit and implicit communication around expectations over time. It is within these powerful moments of difference or privilege that an identity forms (Jones & McEwen, 2000). Throughout the literature there are examples of sorting and tracking practices that send messages to students about who can do mathematics. Stoehr (2015) provides a compelling example of this as a participant recalled an experience in fourth grade in which the “smart students” went to another classroom for mathematics instruction. “This public comparison in which she could not hide nor conceal her status as being considered a ‘regular student’ led her to believe she was not good at mathematics” (Stoehr, 2015, p. 15). Furthermore, when students perceive that mathematics is a White domain and/or a male domain, not all students recognize that they belong (Gutiérrez, 2013; Radovic et al., 2017). Conversely, there are examples throughout the literature that disrupt this notion, such as the study of Railside (Boaler, 2006; Boaler, 2008; Boaler & Staples, 2008). At Railside, teachers intentionally recognized the contributions of low-status students in order to positively influence their beliefs about competence and performance and the perceptions of others (Boaler, 2006; Boaler, 2008; Boaler & Staples, 2008). Strategies like this that equitably recognize competence and contributions to intentionally and strategically develop a positive mathematical identity are noted throughout the Mathematics Teaching Practices: Supporting

Equitable Mathematics Teaching (NCTM, 2014). The emphasis on affective issues related to mathematics learning clearly marks an “identity turn” (Darragh, 2016) and provides hope for achieving access, equity, and empowerment for each and every student through mathematics (NCSM & TODOS, 2016). This is the essence of the joint position statement of NCSM and TODOS (2016) that recognizes access to a high-quality curriculum, effective teaching and learning, and high expectations must be considered through an equity lens.

### **The Opportunity Gap**

Many scholars have studied equity by examining assessment data and the achievement gap. NCTM (2014) acknowledges modest gains made in mathematics achievement regarding existing, persistent gaps as well as highlights new data that continue to “paint a mixed picture of U.S. students’ mathematics achievement” (Larson, 2017). From an international perspective, the Programme for International Student Assessment (PISA) results show a decline in mathematics achievements for 15-year-old students (Organisation for Economic Co-operation and Development [OECD], 2018; NCTM, 2014); however, the Trends in Mathematics and Science Study (TIMSS) suggests steady improvement over time for fourth- and eighth-grade students (Mullis, Martin, Foy, & Hooper, 2016). The 2017 National Assessment of Educational Progress (NAEP) reports that there was no change in mathematics scores in the previous two years. In 2015, “average scores were 1 and 2 points lower in grades 4 and 8, respectively, than the average scores in 2013” (NAEP, 2015). The 2015 NAEP grade 12 mathematics results showed no significant difference and have been stagnant since 1973 (NCTM, 2014). However, analyzing these data through an equity lens confirms that we continue to underserve “too many students—especially those who are poor, nonnative speakers of English, disabled, or members of racial or ethnic minority groups” (NCTM, 2012). Upon further analysis, the NAEP data also reveal an

underrepresentation of females at the top of the distribution despite the fact that many believe equity issues related to gender have been eliminated in mathematics achievement (Cimpian, Lubinski, Timmer, Makowski, & Miller, 2016). However, without context, a focus on the achievement gap perpetuates the harmful hierarchy, stereotypes, and deficit thinking and undermines efforts related to equity in mathematics education (Gutiérrez, 2008; Howard, 2010). Researchers must consider the caution provided by Flores (2007) in which he asserts that a discussion of the achievement gap of certain groups, without also addressing the causes, reinforces a detrimental negative narrative. NCTM (2012) developed a position statement related to the opportunity gap which states:

All students should have the opportunity to receive high-quality mathematics instruction, learn challenging grade-level content, and receive the support necessary to be successful. Much of what has been typically referred to as the “achievement gap” in mathematics is a function of differential instructional opportunities. Differential access to high-quality teachers, instructional opportunities to learn high-quality mathematics, opportunities to learn grade-level mathematics content, and high expectations for mathematics achievement are the main contributors to differential learning outcomes among individuals and groups of students. (p. 1)

Based on this perspective, it is logical to assert that differential access to opportunities also influences the development of a mathematical identity, therefore creating further inequities for students. Framing achievement issues through the opportunity gap lens puts the focus squarely on the systems, structures, and practices in mathematics education rather than the characteristics of the student (Flores, 2007), thus allowing for a broader discussion inclusive of issues related to mathematical identity.



Gutiérrez (2013) is also critical of the excessive focus on the mathematics achievement gap of marginalized students and refers to this as “gap gazing,” which creates narratives about students that become universal truths. It is the subtext of the achievement gap, which is a hierarchical comparison between student groups, which is dangerous and ultimately derails the well-meaning intentions of those committed to equity (Gutiérrez, 2013). Because “gap gazing” has falsely perpetuated the notion that identity is one-dimensional and static, Gutiérrez (2013) urges researchers to foreground issues related to identity in mathematics. Therefore, the following sections will review the literature related to mathematical identity in the context of a high-quality curriculum, effective teaching and learning, and high expectations—characteristics of an equitable mathematics program (NCTM, 2014; NCTM, 2016; NCSM & TODOS, 2016).

### **A High-Quality Curriculum**

Taking a stance to empower students through mathematics requires a commitment to equity which is dependent on students having access to a “high-quality mathematics curriculum, effective teaching and learning, and high expectations” (NCTM, 2014, p. 59). First, it is important to define what is meant by a high-quality mathematics curriculum. Hayes-Jacobs (2010) asserts that a “curriculum should not only focus on the tools necessary to develop reasoned and logical construction of new knowledge in our various fields of study but should also aggressively cultivate a culture that nurtures creativity in all of our learners” (p. 284). Ainsworth (2011) describes a high-quality curriculum as the delivery system that ensures the achievement of learning goals, which is contingent upon the alignment of standards, instruction, and assessment. Building upon this definition, the aim of the Common Core State Standards for Mathematics (CCSSM) was to articulate standards that are focused, coherent, and rigorous, therefore shifting instruction and assessment practices in the same direction and providing the

blueprint for a high-quality curriculum. In addition, NCTM (2014) recommends that a high-quality curriculum is designed in a way that prioritizes time for students to engage in rich tasks, reasoning and sense making, problem solving, and productive discourse; it sequences instruction by first developing conceptual understanding to build procedural fluency (NCTM, 2014). Additionally, a high-quality curriculum should include a focus on developing productive mathematical identities (Grootenboer & Zevenbergen, 2008).

Students who experience a traditional curriculum, focused heavily on procedural understanding implemented through a teacher-centered approach, develop a belief about the nature of mathematics that it is absolute, abstract, and irrelevant to their lives (Boaler, 1998; Boaler, 2002; Boaler & Greeno, 2000; Boaler & Selling, 2017; Boaler et al., 2000). According to Boaler and Greeno (2000), students in a mathematics classroom are *becoming*. Therefore, in classrooms where students are passive receivers of abstract knowledge, this creates a conflict with their notion of self and need for active agency; thus, students reject a future-oriented mathematical identity (Boaler & Greeno, 2000; Boaler & Selling, 2017; Boaler et al., 2000). In contrast, students who experience a problem-solving curriculum tend to develop an active sense of agency and a more productive relationship with mathematics, and therefore a more positive mathematical identity (Boaler & Selling, 2017).

Boaler (1998) conducted a 3-year case study of two schools, Amber Hill and Phoenix Park, which were implementing contrasting mathematics curriculums. Amber Hill's traditional curriculum structured learning experiences through a workbook that "introduced students to the mathematical procedures and techniques and then presented a range of questions for students to practice" (Boaler, 1998, p. 45). In contrast, Phoenix Park implemented a problem-solving, project-based curriculum that, according to Boaler (1998), contributed to an "enhanced

mathematical understanding, higher achievement on tests, and the development of active approaches to knowledge” (Boaler & Selling, 2017, p. 81). Moreover, the Phoenix Hill curriculum, which reflects many of the characteristics of a high-quality curriculum (NCTM, 2014), is also cited as contributing to the productive mathematical identities of the students (Boaler & Selling, 2017).

In a follow-up study conducted 8 years after the students of Phoenix Park and Amber Hill graduated, Boaler interviewed 20 students from the original study to explore whether “the differing forms of identity and expertise that students developed at school persist(ed) into their working lives and impact(ed) their use of mathematics in life” (Boaler & Selling, 2017, p. 82). All 10 students interviewed from Phoenix Park stated that mathematics was useful to their jobs, whereas none of the students from Amber Hill found mathematics beneficial to their jobs. An analysis of employment information indicated that “the Phoenix Park participants exhibited a distinct upward trend in social class that was not evident among the Amber Hill participants” (Boaler & Selling, 2017, p. 87). These findings suggest that beliefs about mathematics, an element of mathematical identity, persist over time and impact professional opportunities. Another important finding from this study is related to ability grouping, a practice utilized at Amber Hill. Although the interview questions were not related to this topic, three students spoke about how this practice limited their opportunities and future potential by creating a “psychological prison” (Boaler & Sterling, 2017, p. 95). This negative expression provides an insight into the current mathematical identity of these three students and the lasting impact of limiting students’ opportunities to experience a high-quality curriculum and the power of not being recognized as mathematical.

Assigning students to certain curriculum tracks, based on their presumed ability, is a

flagrant violation of the access, equity, and empowerment principle (Biafora & Ansalone, 2008; Boaler & Staples, 2008; NCSM & TODOS, 2016; Wager & Foote, 2013; Werblow, Urick, & Duesbery, 2013). Tracing the history of tracking practices in the U.S. evokes outrage as well as an understanding of the resentment many feel about our education system (Biafora & Ansalone, 2008). Students assigned to low-level tracks tend to receive low-level content which is compounded by low expectations (NCTM, 2014). For many students, this becomes the gatekeeper to opportunity rather than the gateway. It is within the power of school districts to eliminate tracking by adopting and embracing equity-driven policies that allow all students to benefit from a high-quality curriculum (NCTM, 2014). In some cases, individual schools and teachers that are committed to equitable practices address issues of tracking with great success. Making changes to deeply rooted, unjust practices and structures is hard, and in such circumstances Heath and Heath (2010) recommend focusing on the bright spots; a shining example of this can be found in the Railside study (Boaler, 2006; Boaler, 2008; Boaler & Staples, 2008).

This 5-year longitudinal, mixed-methods study examined the different access, equity, and empowerment structures and practices of three different high schools and the impact on students (Boaler, 2006; Boaler, 2008; Boaler & Staples, 2008). The researchers noted many differences between the three high schools, primarily the different approaches to instruction. Railside was engaged in reform-based practices as compared to Hilltop and Greendale, which took a traditional approach (Boaler, 2006; Boaler, 2008; Boaler & Staples, 2008). The authors noted many other differences, primarily citing Railside as having practices and structures more aligned to a productive equity stance as compared to Hilltop and Greendale. In addition, Hilltop and Greendale tracked students as they entered high school, whereas the Railside mathematics

“department was deeply committed to the practice of mixed ability teaching and to giving all students equal opportunities for advancement” (Boaler & Staples, 2008, p. 614). The results of this study indicated that students at Railside achieved more, enjoyed mathematics, and were more interested in mathematics as a future career, indicators of a productive mathematical identity (Boaler, 2006; Boaler, 2008; Boaler & Staples, 2008). Although a high-quality curriculum is an important aspect to consider, as it provides the framework for teaching and learning, it is critical to foreground the teaching practices within a mathematics classroom. Throughout the Railside study, examples of equity-based instructional practices are highlighted as the authors emphasize the significance of effective teaching and learning practices that are necessary to realize the benefits of a high-quality curriculum (Boaler & Staples, 2008).

### **Effective Teaching and Learning**

Effective teaching and learning that is also socially just is complex yet achievable. Many scholars agree “that perhaps the single most important act that can be done to reverse disparities of educational opportunities and outcomes is to ensure that all students have highly qualified teachers in their classrooms, particularly in those schools where underachievement has remained prevalent” (Howard, 2010, p. 33). NCTM’s call for “systemic excellence” (NCTM, 2014, p. 3) requires “improving as an individual, raising the performance of the team, and increasing quality across the whole profession” (Hargreaves & Fullan, 2013, p. 23). One place to start is to better understand the individual, in this case the teacher of mathematics, and, even more specifically, the elementary teacher of mathematics.

It is widely accepted that the teacher’s practices matter (Ball & Forzani, 2011; Darling-Hammond, 2000; Sanders, Wright, & Horn, 1997). Therefore, the National Council of Teachers of Mathematics (NCTM) has identified eight Mathematics Teaching Practices (NCTM, 2014)

that provide a structure for creating mathematical experiences that “empower (people) to become creative and confident solvers of problems” (Ernest, 1989, p. 20). These eight Mathematics

Teaching Practices include:

1. establishing goals to focus learning;
2. implementing tasks that promote reasoning and problem solving;
3. using and connecting mathematical representations;
4. facilitating meaningful mathematical discourse;
5. posing purposeful questions;
6. building procedural fluency from conceptual understanding;
7. supporting productive struggle in learning mathematics; and
8. eliciting evidence of student thinking. (NCTM, 2014, p. 10)

The successful implementation of these eight practices is contingent on many factors that have the potential to create opportunities and opportunity gaps for students. Teaching and learning stops short if it only attends to learning concepts and developing skills. Effective teaching and learning also includes an intentional focus on cultivating mathematical identities and agency (NCTM, 2018). To provide clarity and direction, *Catalyzing Change in High School Mathematics: Initiating Critical Conversations* (NCTM, 2018) provides a crosswalk between the Mathematics Teaching Practices (NCTM, 2014) and equitable teaching practices and states that “implementing equitable instructional practices is an action teachers can undertake immediately to improve the experience and learning outcomes for their students” (p. 25). For each of the eight Mathematics Teaching Practices NCTM (2018), has provided guidance on practices to develop identity and agency. The authors point out that this is not an exhaustive list of recommendations, but rather to “provoke ideas and serve as a first step for teaches who are intentional about

implementing equitable teaching practice” (NCTM, 2018, p. 31). To that point, the successful implementation of these practices is highly dependent on the knowledge, beliefs, and attitudes of the mathematics teacher (Ernest, 1989), critical issues to explore as we collectively seek to empower others through mathematics.

In the simplest terms, and within the context of teaching, teacher knowledge frameworks generally consist of both content knowledge and pedagogical knowledge (Ernest, 1989; Hill & Ball, 2004; Ma, 1999; Shulman, 1986/2013). Shulman’s seminal work was punctuated with his concluding remarks, “Those who can, do. Those who understand, teach” (Shulman, 1986/2013, p. 11). He prefaces this by leading the reader through a narrative description of the conception and importance of his theoretical framework for teacher knowledge. Shulman (1986/2013) “distinguishes . . . the knowledge that grows in the minds of teachers . . . among three categories: (a) subject matter content knowledge, (b) pedagogical content knowledge, and (c) curricular knowledge” (p. 9/p. 6). Many scholars have gone on to expand upon Shulman’s framework; providing significant contributions to the understanding of teacher knowledge and its implication to practice.

Ernest’s model (1989) includes the work of Shulman (1986) but adds three additional categories: (1) knowledge of other subject matter consisting of the application of mathematics across various disciplines; (2) knowledge of organization for teaching mathematics including classroom management, logistics, and group structures and; (3) knowledge of the context of teaching addressing various aspects of the school setting and knowledge of education, a broad category which includes a range of topics from educational psychology to student diversity (Ernest, 1989). Ernest’s additional categories are so broad they provide more of a spotlight on knowledge rather than a laser-like focus, which perhaps was his intention.

A noted contribution in this area of research was made by Ma (1999/2010), a doctoral student of Shulman. Ma's (1999/2010) international comparative study of the mathematics knowledge of teachers concluded that:

Although the intent of my study was not to evaluate U.S. and Chinese teachers' mathematical knowledge, it has revealed some important differences in their knowledge of school mathematics. It does not seem to be an accident that not one in a group of above average U.S. teachers displayed a profound understanding of elementary mathematics. In fact, the knowledge gap between the U.S. and Chinese teachers parallels the learning gap between U.S. and Chinese students revealed by other scholars. (p. 144)

In the foreword to *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*, Shulman suggests that Ma's work "appears to be about understanding the content of mathematics, rather than its pedagogy, but its conception of content is profoundly pedagogical" (Ma, 2010). Once again, Shulman is positioning the bridge between content knowledge and pedagogical knowledge that is fundamental to his framework (1986/2013). Ma (2010) concludes by restating the importance of improving teacher knowledge in an effort to improve mathematics instruction.

Although Ball et al. (2008) added categories to Shulman's framework (1986/2013), there is a definite sense of cohesiveness between the categories. The Mathematical Knowledge for Teaching model (Figure 5) was developed "bottom up, beginning with practice" (Ball et al., 2008, p. 395) with a focus on teaching, not teachers (Ball, et al., 2008). To address the lack of measures to evaluate knowledge for teaching mathematics, Hill, Schilling, and Ball (2004) developed the Mathematical Knowledge for Teaching Measures. The Mathematical Knowledge for Teaching (MKT) model and measures offer tools that many scholars have utilized to advance



the understanding of knowledge and the implications for practice and student learning (Ball et al., 2008). It is clear that deeply developed MKT is required to effectively implement the mathematics teaching practices, and many studies indicate that students living in poverty tend to have teachers with less developed MKT (NCTM, 2014).

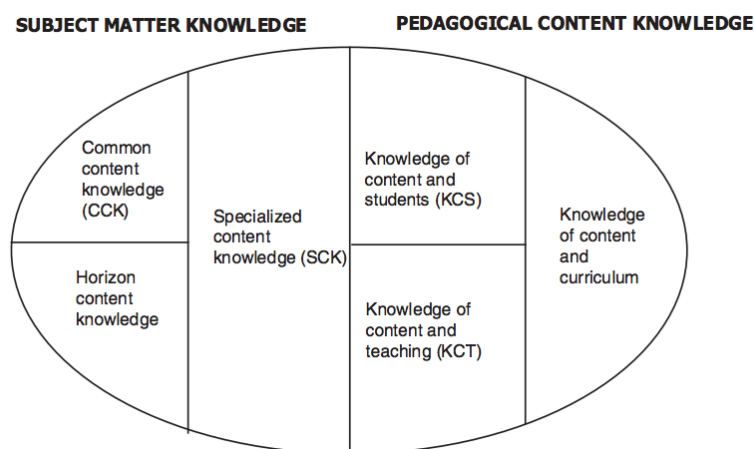


Figure 5 Domains of Mathematical Knowledge for Teaching (Ball et al., 2008)

An example of this inequity can be found in a study conducted by Wimer, Ridenour, Thomas, and Place (2001) in which the researchers observed the “interactive patterns of teachers and students . . . specifically to explore higher order teacher questioning” (p. 84). Higher order questions “assess and advance students’ reasoning and sense making about important mathematical ideas and relationships” (NCTM, 2014, p. 10), thus leading to higher level learning (Wimer et al., 2001). Although the researchers posited that there would be a difference in the level of questions based on gender, the results were inconclusive (Wimer et al., 2001). However, the researchers noted the lack of higher order questions in general (Wimer et al., 2001). This may suggest that the teachers in this study have less developed MKT, therefore creating a potential opportunity gap for the students in those classrooms. Higher order questions or “purposeful questions” are directly related to “facilitating meaningful mathematical discourse” both of which

are included in NCTM's Mathematics Teaching Practices (2014). The importance of MKT is well documented. However, because this framework is cognitive in nature, it does not attend to aspects of sociocultural learning that help to further understand and describe effective teaching practices.

Applying a sociocultural lens to the MKT framework, particularly the construct of Knowledge of Content and Students (KCS), allows researchers to consider the relationship between a teacher and student and the knowledge a teacher holds regarding the multiple identities students bring with them to the mathematics context. "Teachers must know content (the *what* of teaching) and must be experts in pedagogy (the *how*, or the art of teaching), but most importantly, teachers must know *who* they are teaching" (Haberman et al., 2018, p. 93). Ladson-Billings (1995) draws our attention to the pedagogical excellence of eight teachers of African American students and states that their success is more than just good teaching; it is culturally relevant teaching. Ladson-Billings (1995) found that effective teachers "kept the relations between themselves and their students fluid and equitable. These fluid relationships extended beyond the classroom and into the community" (p. 163). The aim of culturally relevant pedagogy, as defined by Ladson-Billings (1995), is academic success, cultural competence, and critical consciousness while attending to the conceptions of self and others, social relationships, and the conceptions of knowledge. Since 1995, scholars and practitioners have embraced culturally relevant pedagogy and more recently have iterated upon this work by suggesting a new term—*culturally sustaining pedagogy* (Paris, 2012).

Culturally sustaining pedagogy, proposed by Paris (2012), "seeks to perpetuate and foster—to sustain—linguistic, literate, and cultural pluralism as part of the democratic project of schooling" (p. 93). Paris (2012) acknowledges Ladson-Billings's aim and suggests the term

*relevant* simply does not go far enough to articulate the goal. Ladson-Billings (2014) supports “culturally sustaining pedagogy as a way to push forward her original goals of engaging critically in the cultural landscapes of classrooms” (p. 74). Ladson-Billings (2014) suggests that “the real beauty of culturally sustaining pedagogy . . . is the ability to take on the dual responsibility of external performance assessments as well as community and student-driven learning” (pp. 83–84). A culturally sustaining pedagogy that focuses on academic success, cultural competence, and critical consciousness provides the means to disrupt the *pedagogy of poverty* that many students continue to experience in mathematics classrooms today (Ladson-Billings, 1997; Haberman, 1991/2010).

Based on deficit thinking about students, a pedagogy of poverty prioritizes basic skills through directive pedagogy (Haberman, 1991/2010). Evidence to discredit this deficit approach to pedagogy can be found in the research related to the New Zealand Numeracy Development Professional Project. In a South Auckland school, within a Pasifika community with high poverty, high unemployment, and high crime rates (Nakhid, 2012), Woodard and Irwin (2005) noticed that in one particular classroom a teacher’s follow-up questions tended to request students to justify their mathematical thinking, an inherent aspect in both the eight Mathematics Teaching Practices (NCTM, 2014) and the Standards for Mathematical Practice (CCSSM). This pattern of reasoning and sense making through discourse was then observed in the behaviors of students (Woodward & Irwin, 2005), therefore suggesting a positive influence on student learning. Researchers noted greater than average progress in this classroom as compared to other Pasifika students nationwide. Because learning and identity formation are bidirectional, this type of practice simultaneously improves both (Nasir & de Royston, 2013). As an important note related to access and equity, the researchers observed the productive discourse patterns of

teachers were the same, regardless of the presumed ability of the student (Woodward & Irwin, 2005). This was interpreted as the teacher having high expectations for all students and providing an opportunity for all students to engage in academically productive discourse (Woodward & Irwin, 2005).

### **High Expectations**

Holding high expectations for all students increases the opportunities that students have to engage in mathematics in meaningful ways. It begins by rejecting a belief dating back 2,300 years to Plato's *Republic*, in which he argued that those who possess a superior ability in mathematics would be the guardians of the city and have a place in the halls of gods (Stinson, 2004), a belief that still dominates exclusionary practices in mathematics and stratifies students in highly oppressive ways. In contrast, high expectations rely on a genuine belief that all students are capable of constructing solutions to complex problems and contributing to the world through mathematics. "The cumulative research on the effects of teacher expectations has led contemporary scholars and educational professionals to advocate high expectations as a key principle of effective teaching" (Martínez, Martínez, & Mizala, 2015, p. 71). Because mathematical identity not only includes a perception of self but the perceptions of others, these perceptions matter because they ultimately become performance expectations (Cribbs et al., 2015). Walshaw (2007) asserts that a mathematical identity is "formed in a very slippery space . . . where affective issues always intervene . . . and desires, hopes, and anxiety become highly influential" (p. 97).

In a study conducted by Martínez et al. (2015), the researchers hypothesized that the mathematics anxiety of the preservice elementary teachers plays a significant role in the expectations of female students and students with low socioeconomic status. Through an

experimental design, the researchers surveyed 208 preservice teachers, 176 females and 32 males, to assess their academic expectations of hypothetical students. The researchers also implemented the Abbreviated Mathematics Anxiety Rating Scale (A-MARS, Alexander & Martray, 1989) to determine the preservice teachers' current level of mathematics anxiety (Martínez et al., 2015). The conclusions of this study suggest that “preservice elementary school teachers project their own mathematics anxiety on the expectations they form about their students” (Martínez et al., 2015, p. 75). In this study, preservice teachers with mathematics anxiety above the median range had lower expectations of both female students as well as of students with a low socioeconomic status (Martínez et al., 2015). Because this study is situated within a positivist paradigm, the discussion does not extend to how and why this phenomenon occurs. To provide a more robust understanding of the interrelated nature of expectations, mathematics anxiety, and mathematical identity, it is beneficial to examine related qualitative studies.

Stoehr (2015, 2017) conducted a case study, using a narrative approach, which explored the mathematics anxiety of female preservice elementary teachers. Because 89% of elementary teachers are female (Taie & Goldring, 2017) and many females report perceptions of low expectations to excel in mathematics and high levels of mathematics anxiety, this is an important research focus (Stoehr, 2015, 2017). In this study, the analysis of the female participants' autobiographies revealed high levels of mathematics anxiety and lack of confidence to learn and teach mathematics. One participant recalled an experience in fourth grade in which the “smart students” went to another classroom for mathematics instruction. “This public comparison in which she could not hide nor conceal her status as being considered a ‘regular student’ led her to believe she was not good at mathematics” (Stoehr, 2015, p. 15). This was a turning point in her

relationship with mathematics and the beginning of her mathematics anxiety (Stoehr, 2015, 2017). By analyzing both life-story narratives as well as a through detailed retelling of a well-remembered event, as reported in this study, mathematics researchers and practitioners gain a deeper understanding about mathematics anxiety that can provide insights into practices that are detrimental to becoming mathematical. This understanding combined with the insights of Martínez et al., (2015) should receive priority attention for those who prepare the next generation of elementary educators.

Adopting a stance related to the incremental theory of intelligence, or growth mindset, as well as being acutely aware of the entity theory of intelligence, or fixed mindset (Murphy & Dweck, 2010), has the potential to mitigate mathematics anxiety and the perceived low expectations placed on students that are associated with it. Low expectations are entangled in a fixed mindset, whereas high expectations for all students are grounded in the belief that all students have the capacity to deeply learn and apply mathematics in meaningful ways (Boaler, 2013). High expectations are generally outwardly communicated and consciously held. Low expectations tend to be unspoken and at times masked as well intended, empathetic statements of support (Rattan et al., 2012). In a study conducted by Rattan et al. (2012), the researchers hypothesized that college students receiving “comfort feedback” would decrease effort and engagement, thus lowering their own expectations. Their findings suggest that participants who received comfort feedback perceived their professor as having significantly lower expectations and investment, cited decreased motivation, and reduced expectations for their final grade (Rattan et al., 2012). The power of feedback to transmit low expectations inadvertently must be closely monitored by educators to ensure that students develop productive mindsets about mathematics.

Grades are a type of feedback that should communicate high expectations for a student's proficiency related to rigorous learning goals within the progressions of the standards. According to Flores (2007), inflating grades as a type of comfort feedback signals low expectations and ultimately sets the student up for failure in the future. All too often, students define themselves by the grades they receive, "I'm an A student in mathematics" or "I'm a D student in mathematics," which sets expectations for both teachers and students that become a part of a mathematical identity (Boaler, 2016). Boaler (2016) argues that in order "to teach students a growth mindset and general positive messages about mathematics learning, teachers should abandon testing and grading as much as possible" (p. 16). However, the reality is that grading is required; therefore Reeves (2011) suggests that in order for grades to be effective they must be accurate, fair, specific, and timely. Focusing on effective grading practices sets high expectations for all students. Furthermore, Hattie (2008) found that effective feedback has a high impact on student learning with an effect size of (.73). Feedback is a powerful practice than not only advances student learning but when employed strategically can create more equitable interactions between students.

Complex instruction is a type of feedback strategy used by teachers with an equity stance (Bannister, 2016) and has the power to communicate high expectations for learning as well as develop relational equity (Boaler, 2008). Within complex instruction, teachers "assign competence" which "disrupts the pecking order and boosts the participation of low status students . . . through the teachers' public, positive, evaluative statement that specifically recognizes the intellectual contribution a student has made to a group task" (Bannister, 2016, p. 343). Complex instruction is an example of an equity-based practice, and within this practice the identity of the participants is mediating the transformative interactions (Walshaw, 2011).

“Practices at both the micro level of the classroom and the macro level of the institution of schooling—and the power plays within—all work to inform the development of an equitable practice within mathematics education” (Walshaw, 2011, p. 97). In turn, the mathematical identity of the student reveals the quality and impact of equitable pedagogic action (Walshaw, 2011).

### **Conclusion**

Inspiring a culture of mathematics achievement for each and every student begins with a commitment to equity. This commitment is based upon a genuine pursuit to uphold the democratic principles that underpin the education system in the United States. This requires researchers and practitioners to not only critically examine “the taken-for-granted rules and ways of operating that privilege some individuals and exclude others” (Gutiérrez, 2013, p. 40), but to utilize that insight and evidence to drive change. Over the last two decades both the insight and evidence, as it relates to equity, has evolved. In *Principles and Standards for School Mathematics* (NCTM, 2000), equity was included as one of the six principles to achieve NCTM’s vision for school mathematics. This early equity principle primarily focused on setting high expectations and providing strong support. In 2014, NCTM released *Principles to Actions* and expanded upon the earlier equity principle by officially including access in the title of the principle, a construct that was alluded to in the previous version but not fully articulated. Within this revised access and equity principle, the authors opened the door to a deeper conversation related to access and the opportunity gaps that exist for too many students (NCTM, 2014). However, critics challenged this revised principle stating it did not go far enough. NCTM acknowledged that previous reform efforts “focused on standards, curriculum, instructional practices, and assessment, and that [they] have too often addressed these issues in



decontextualized ways that have frequently ignored the experiences and realities of children's lives" (Larson, 2016, para 3). The collective commitment of NCTM, NCSM, TODOS, scholars, and practitioners was the impetus for expanding this principle to include empowerment "to capture the critical constructs of students' mathematical identities, sense of agency, and social justice" (Larson, 2016, para. 5).

According to Larson (2016), we must examine what happens to students once they have access, as equity and empowerment are mediated and filtered through the sociocultural context—the mathematics classroom. A hierarchy exists within many classrooms, positioning the teacher with the greatest power (Ladson-Billings, 1995). The heart of equity in the classroom is dependent on the teacher's awareness of the power and how it is utilized. Ladson-Billings (1995) noted in her seminal research that effective teachers positioned themselves as both a teacher and a learner within their classrooms. Students were also positioned as teachers and students, thus creating a collaborative community of learners built upon relational equity (1995). "Progressive socially just pedagogic action . . . conceives of the learner as the producer of knowledge and understands teachers as co-producers" (p. 93). Supporting teachers in becoming a transformative agent of equitable pedagogic action requires foregrounding both cognitive and affective aspects of teaching and learning. It acknowledges that developing a robust mathematical identity requires knowledge and skills but is ultimately dependent on affective elements such as attitudes, beliefs, and emotions. Although the primary focus of research has been understanding the mathematical identity of students (Darragh, 2016), in order to catalyze change, there must be an equal emphasis on the mathematical identity of teachers, as "the work of justice lives inside the work of teaching" (Ball, 2017) and "the concept of identity at the heart of a quality and equitable mathematics experience is an extremely complex phenomenon" (Walshaw, 2011, p. 101).

## **Chapter 3: Methodology**

### **Introduction**

A researcher's paradigmatic view of the world guides the approach and the methods of a study. This study is situated within a constructivist paradigm, as the researcher seeks to understand a phenomenon and "sees the world as complex and interconnected" (Shkedi, 2005, p. 3). The ontology, epistemology, and methodology of the study must then be aligned to a constructivist perspective in order to create coherence and unity. "A constructivist adopts a relativist ontology, a transactional epistemology, and a hermeneutic, dialectical methodology" (Denzin & Lincoln, 2018, p. 98). According to Guba (1990), a relativist ontology asserts that "realities exist in the form of multiple mental constructions, socially and experientially based, local and specific, dependent for their form and content on the persons that hold them" (as cited in Lincoln, Lynham, & Guba, 2018, p. 114). A transactional epistemology is the assumption that meaning is co-created and the lived experiences of the researcher and the participants will shape the data and findings (Lincoln et al., 2018). A constructivist methodology must be both hermeneutic and dialectic, meaning that the current reality of the participants is interpreted, logically synthesized (Lincoln et al., 2018), and represented as a heterarchical complex web of meaning (Shkedi, 2005). Within a constructivist paradigm, the meaning-making activities of a phenomenon occur within a social context and shape action or inaction (Lincoln et al., 2018). The overarching goal of this study was to gain insights into how preservice teachers' mathematical identities develop and how that might contribute to the shaping of learning experiences that lead to more equitable experiences in mathematics (Lincoln et al., 2018). Therefore, the principles of a qualitative methodology are aligned to both the researcher's paradigm, the overarching goal, and the purpose of this study.

### **Purpose of the Study**

The purpose of this study was to contribute to the understanding of the mathematical identity of preservice teachers and their perceptions of equity, as the hope for realizing the promise of education rests on the shoulders of the next generation and all those who support their efforts. Foregrounding mathematical identity acknowledges the importance of understanding the whole teacher as both the heart and mind orchestrate the learning experiences within a classroom (McCray & Chen, 2012). According to McCray and Chen (2012), a “teacher’s sense of self, beliefs, and existing knowledge will be influenced by their previous life experiences, schooling, and school system” (p. 136). These experiences are part of temporal whole and, when reflected upon or communicated, are generally expressed narratively (Shkedi, 2005). It is through these narratives that this study gained insight about the mathematical identity of preservice teachers and their perceptions of equity. These insights will provide a pragmatic contribution for those who support teacher growth and development, particularly teacher preparation programs, school districts, and professional learning organizations.

### **Research Design**

Mathematical identity is a complex topic; therefore, scholars have primarily utilized a qualitative approach to provide in-depth, rich descriptions (Darragh, 2016). Based on a qualitative constructivist approach, the design of this study embraced a case study methodology as a means “to describe and explain how everyday practices in specific places are connected to the large structure and processes” (Schwandt & Gates, 2018, p. 345). Marshall and Rossman (2016) suggest the popularity of the case study method is due to the “explicit focus on context and dynamic interactions, often over time” (p. 19). Although case study methodology is widely used in education research, it lacks a clearly defined structure and protocol (Yazan, 2015).

However, it is generally agreed upon that, within case study research, questions are “how” questions, the researcher has no control over the events, and the topic is considered a contemporary phenomenon (Yin, 2014). Additionally, Merriam (1988) suggests that the case is a bounded system, and the end product of a case study is “a holistic, intensive description and interpretation of a contemporary phenomenon” (p. 9). Stake (1995) contends that “a case study is both a process of inquiry about the case and a product of that inquiry” (p. 436). According to Schwant and Gates (2018) refer to case study methodology as “neither a straightforward or uncomplicated undertaking” (p. 341). Further adding to the ambiguity around case study research is the multiple perspectives of the three seminal methodologists: Merriam (1988), Stake (1995), and Yin (2014). Although there is much to glean from each, this study was grounded in the work of Merriam (1988) as Yin’s approach leans towards positivism and Stake’s approach is more philosophical in nature, making it difficult to follow (Yazan, 2015). Merriam’s approach provides the structure and flexibility needed to guide the design of this case study.

According to Merriam (1988), case studies can be described by the end product, which is either descriptive, interpretive, or evaluative. This study is considered both a descriptive and an interpretive case study because it seeks to “provide a detailed account of the phenomenon under study [and] to illustrate, support, or challenge assumptions held prior to the data collection” (Merriam, 1988, pp. 27–28). Furthermore, Merriam and Tisdell (2016) state that “a case is a noun, a thing, an entity; it is seldom a verb, a participle, a functioning” (p. 38). The case must be bound intrinsically (Merriam & Tisdell, 2016), “delimited by the participant, by time, and by place” (Creswell & Poth, 2018, p. 120). The case in this study was the mathematical identity of preservice teachers, in their third year of a teacher preparation program, enrolled in a mathematics teaching methods course in a large Midwestern university during the fall semester.

## **Research Questions**

Developing the research questions is the most important step in designing a research study as they establish the frame in which all of the pieces must fit (Yin, 2014). According to Marshall and Rossman (2016), qualitative research questions should be focused yet flexible as this allows the researcher to refine the questions during the data collection process but also limits the scope of inquiry, thus honoring the inductive nature of qualitative research. Merriam (1998) suggests that case study questions focus on the why or how of a process and understanding that process through what, why, and how questions. This is aligned to the recommendation of Creswell and Poth (2018) in which they describe the need for a central question that is broad but also captures the essence of the study and is followed by associated subquestions. The following are the final research questions that were refined through data collection and analysis:

Central research question: How are the mathematical identities of preservice teachers shaped?

1. How do beliefs about mathematics competence and performance develop and how do they shape the mathematical identity of preservice teachers?
2. How do beliefs about recognition develop and how do they shape the mathematical identity of preservice teachers?
3. How does interest in mathematics develop and how does that shape the mathematical identity of preservice teachers?
4. How do perceptions of equity develop and how do they shape the mathematical identity of preservice teachers?

## **Setting**

The setting for this study was an undergraduate mathematics teaching methods course at a large Midwestern public research institution. The university makes up approximately 25% of

the total population of the city in which it is located. According the university's website, in the fall of 2017, approximately 25,000 students were enrolled. Of those students, 79% of the students identified as non-minorities, 51% identified as female, 60% were residents of the state, and 91% were domestic students. There are 13 academic schools within the university, and the participants of this study were enrolled in the fourth largest school– the School of Education. The participant setting was a required elementary mathematics teaching methods course. There were two sections of the mathematics methods course that met twice per week for 75 minutes each on campus. When the participants were not on campus, they were engaged in a field experience at an elementary school. Access to the setting and participants was arranged through the instructor. Over the last year the researcher has attended and observed in this setting and taught a lesson on one occasion. Additionally, the researcher utilized this setting during the previous school year to develop the data collection methods and skills that were employed in this study.

### **Participants**

The participants of the study were eight elementary preservice teachers in their junior year of their teacher preparation program. Generally, during the fall of the third year of the teacher preparation program, students simultaneously enroll in the mathematics teaching methods course and a mathematics content course which provided an opportunity to explore an information-rich case. As such, this aligns to purposeful sampling which “is based on the assumption that the investigator wants to discover, understand, and gain insight, therefore must select a sample from which the most can be learned” Merriam & Tisdell, 2016, p. 96). The researcher believes that there is something to be learned from everyone's story, therefore rejecting the notion of typical and unique cases based on the belief that the criteria to determine such cases may perpetuate a detrimental narrative of other and has the potential to bias the study.

Furthermore, this aligns to the justice principle guiding ethical research which seeks to enhance inclusivity (Creswell & Poth, 2018). A convenience sample was utilized as all students enrolled in both the mathematics teaching methods course and the mathematics content course were asked to participate (Appendix A). Enrollment in the mathematics content course provided a current mathematics learning context that participants were able to reflect upon as it related to their mathematical identity. Eight participants volunteered to participate in this study out of a total 36 potential participants enrolled in the mathematics teaching methods course. According to Creswell and Poth (2018) this sample size was appropriate for developing themes and conducting analysis. A signed consent was obtained for the participants (Appendix B).

### **Role of the Researcher**

The role of the researcher in this study was an observer as a nonparticipant (Marshall & Rossman, 2016). The researcher did not have a formal role in the setting but did develop a relationship with the participants to increase the accuracy of the findings (Creswell & Creswell, 2018). It was essential in establishing the trustworthiness of this study for the researcher to identify bias, values, and, personal background (Creswell & Poth, 2018).

According to Merriam (1988), “the interviewer/respondent interaction is a complex phenomenon. Both parties bring biases, predispositions, and attitudes that color the interaction and the data elicited” (p. 76). Because the majority of the participants were about the same age as the researcher’s own children, this naturally brought the lens of a parent to the process. At times the researcher had to temper nurturing words of encouragement or support as the participants described challenging experiences. Additionally, as an educator the researcher’s tendency was to use the conversations to shape productive beliefs. The researcher was consciously aware of this during the interviews and was cautious not to respond in a way that could potentially shape

future responses by the participants. Furthermore, as the participants shared their stories, the researcher generally had something in common with each of them. For example, one of the participants grew up in the same area as the researcher. Because of this, the researcher had a preconceived notion of the participant's experiences, however it was important not to filter the conversations through the assumption that the lived experiences of the participant and the researcher were the same. The researcher paid careful attention to this during the data analysis process.

The researcher received both her bachelor's degree and master's degree from the university in which the study was conducted. For 10 years, the researcher taught in three different Title I schools in a metropolitan area near the university. The primary teaching experience was in kindergarten, and the researcher's primary focus was on literacy. The researcher's attention did not turn to mathematics teaching and learning until admission to a doctoral program in 2013. For the past 14 years, the researcher has worked for a large educational learning company, and in the last 9 years has been focused on professional learning for teachers and leaders. Currently, the researcher leads the product management and strategy for mathematics professional learning. The researcher did not disclose her professional identity to the participants until after the member check, as this may have created a potential ethical issue. In a previous experience, a preservice teacher, who had been observed and interviewed by the researcher, inquired about a summer internship. Instead, during data collection, the researcher shared with the participants her academic identity as a doctoral candidate at the university.

### **Data Collection**

The goal of this case study was to provide an in-depth understanding of the mathematical identity of preservice teachers. Accomplishing this required drawing on multiple data collection



methods, primarily interviews and documents (Creswell & Poth, 2018). According to Merriam (1988), this is also a strength of case study research as it allows for methodological triangulation. This study used both unstructured (Appendix C) and semistructured interviews (Appendix D) at different points in time. An unstructured interview allowed the participants to express their reality without constraint whereas the semistructured interview allowed the researcher to guide the interview to maintain the focus of the study (Merriam & Tisdell, 2016). Creswell and Creswell (2018) state that interviews are advantageous because they allow participants to provide historical information, which is particularly relevant to this study. However, it is also important to note the limitations of interviews which include “the researcher’s presence may bias responses, and not all people are equally articulate and perceptive” (p. 187). Additionally, data were collected through a personal document, the participant’s mathematics autobiography assignment (Merriam & Tisdell, 2016). Creswell and Creswell (2018) cite many advantages to data gathered from documents like the mathematics autobiographies, as this is generally unobtrusive and “enables a researcher to obtain language and words of the participants” (p. 187). Limitations of documents are similar to interviews in that not all participants are equally skilled writers (Creswell & Creswell, 2018). The researcher was aware of these limitations throughout the data analysis process as well as in the generation of the findings.

First, a 30-minute unstructured interview was conducted. During this interview participants were asked to retell their mathematics autobiography. The researcher did not take written notes during the interview but used a recording device and later had the interviews transcribed. Next, the researcher collected the mathematics autobiographies from the instructor for each student; this was an assignment for all of the students in the mathematics methods course. Based on the first interview and the autobiography, the researcher generated additional

questions for the semistructured interviews for each participant. This was a longer interview, approximately 60 minutes; again, the researcher did not take notes during this interview but recorded the interview that was later transcribed. The final interview, lasting approximately 30 minutes in a group setting, presented the initial descriptive and interpretive analysis for each participant to ensure accuracy. Each participant was asked to make edits and to provide any clarifications to the findings.

### **Data Organization**

Organizing and protecting the data were important considerations in establishing the trustworthiness of this study. This included protecting the privacy of the participants and their data. At the beginning of the study each participant was assigned a letter, A through H. This letter was used to tag all of the data collected from each participant, and no personal information was associated with the data. Raw data were stored on the researcher's password-protected personal cell phone and iPad in the Rev recording application on each device. Rev, an online transcription service, allowed the audio recording to be easily transmitted and stored using 128-bit SSL encryption. Rev transcribed each interview and then the verbatim transcription was sent through email to the researcher. The researcher then uploaded the transcript to Atlas.ti qualitative analysis software. The mathematics autobiographies were also uploaded and stored in the Atlas.ti software; the data within Atlas.ti was also password protected. Hard copies of the data have been kept and stored in a secure location. Appendix E describes the data collection plan.

It is widely understood that a qualitative case study has the potential to produce significant amounts of data; therefore, it was incumbent upon the researcher to establish a case study database (Merriam & Tisdell, 2016). In addition to the amount of data, the range of data sources was a challenge due to the potential "disparate, incompatible, even apparently

contradictory information” (Merriam & Tisdell, 2016, p. 233), thus making data management critical for data analysis. The case study database was organized by a scheme determined during the process so that the data were easily retrievable during data analysis (Merriam & Tisdell, 2016). Beyond the practical and logistical considerations regarding data organization, many qualitative methodologists consider data organization the first phase of data analysis (Creswell & Creswell, 2018; Creswell & Poth, 2018, Merriam, 1988; Merriam & Tisdell, 2016). In particular, this is the intentional selection of relevant data and the potential exclusion of cases if necessary (Shkedi, 2005). With a process and structure for data organization and management in place, the researcher can focus on the interaction between data collection and data analysis (Shkedi, 2005).

### **Data Analysis**

Data collection and data analysis happen simultaneously in a qualitative case study; it is recursive and dynamic (Merriam, 1988). According to Merriam and Tisdell (2016), the ongoing analysis lends itself to a process and data that are focused and manageable (Figure 6). It is this emergent design that allows the researcher to refine the research questions as the focus moves from the particular to the general (Creswell & Creswell, 2018; Creswell & Poth, 2018; Merriam & Tisdell, 2016). When moving from the particular to the general, the researcher makes meaning through the categorization process (Shkedi, 2005). The categories structure the answers to the research questions; therefore, the initial data analysis began with identifying units of data that were aligned to the research questions (Merriam & Tisdell, 2016). The units of data must be both relevant and the smallest amount of information that is still meaningful without context (Merriam & Tisdell, 2016). Each unit of data was then assigned a code. In addition to coding the data, the researcher wrote informal memos while reading the data as a means to capture ideas,

suggestions about the data, and to engage in an “ongoing process of deliberation” (Shkedi, 2005, p. 89).

In this study, the unstructured interviews were analyzed first by assigning each unit of data an open code. The open codes were then grouped together to create axial codes (Merriam & Tisdell, 2016). The axial codes were then used as the researcher compared the codes looking for recurring regularities or patterns for each participant and across participants (Merriam & Tisdell, 2016). A similar process was followed for the mathematics autobiographies and the semistructured interviews. Once all of the data had been collected and coded, the data analysis process became more intensive (Merriam, 1988). It was then through inductive and deductive reasoning about the axial codes that categories were assigned (Merriam & Tisdell, 2016). The categories identified were beliefs about competence and performance, beliefs about recognition, and interest. At first, these categories were resisted because aligning directly to the model for mathematics identity (Cribbs et al., 2015) felt as if this study was slipping into a positivist paradigm. However, since this model is one of the conceptual frameworks guiding this study, it was embraced, and the data were further examined with that focus. The category of perceptions of equity was refined to perceptions of equity through salient identities, and perceptions of equity through sociocultural experiences. Once the categories were determined, the data was reviewed again to identify relevant data associated with the categories (Merriam, 1988). This information shaped the refinement of the research questions and the descriptive and interpretive narratives for each participant.

Using the conceptual frameworks guiding this study, an analysis of the descriptive and interpretive narratives was conducted. The conceptual frameworks were used as a means to trace the relationship the participants’ described between the categories. From this, a data map was

generated for each participant. Finally, themes were identified, and the data maps were refined to reflect the relationship between the themes and the categories (Appendix F). The themes ultimately answered the research questions and led to the development of the end product of the study. The end product, the findings of this case study, is a descriptive and interpretive analysis of mathematical identity and perceptions of equity that align to the central research question and the four subquestions.

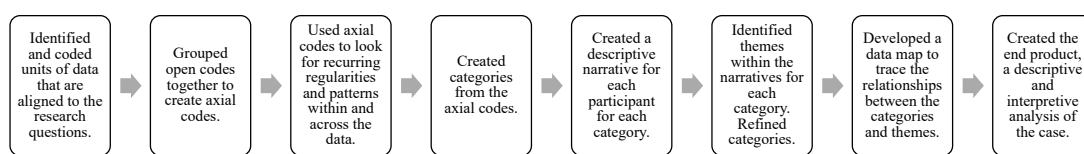


Figure 6 Data Analysis Process, Adapted (Merriam & Tisdell, 2016)

### Trustworthiness

Trustworthiness is based on a rigorously conducted study that provides insights and credible findings. Lincoln et al. (2018) suggest the researcher of a trustworthy study would assert that the findings are authentic, and the implications are worthy of action. To establish trustworthiness, qualitative researchers must ensure methodological and interpretative rigor as it relates to credibility, dependability, confirmability, and transferability (Lincoln et al., 2018; Merriam & Tisdell, 2016). The credibility of this study was established through the triangulation of data methods, rich thick descriptions, and member checks (Creswell & Poth, 2018; Marshall & Rossman, 2016). Dependability rests on the assurance that the researcher will “account for changing conditions in the phenomenon chosen for study and changes in the design caused by an increasingly refined understanding of the setting” (Marshall & Rossman, 2016, p. 262). Through the use of a critical friend, confirmability was established (Marshall & Rossman, 2016). Finally, the transferability of this study took into consideration “ways the study’s findings will be useful

to others in similar situations, with similar research questions or questions of practice” (Marshall & Rossman, 2016, p. 261). The researcher was in relentless pursuit of transferability.

### **Limitations**

It is important to note the limitations of this study. A primary limitation was the convenience sampling method. Participants volunteered to participate in this study as one of three options to fulfill a course assignment. Overall, the participants described an interest in mathematics, therefore generating questions about those who chose not to participate and why. It would have been interesting to examine the mathematics autobiographies of the students not in the study to understand if interest in the study was related to interest in mathematics. Furthermore, as mentioned in the methodology, the primary method for data collection was the unstructured and semistructured interview. Interviews have an inherent limitation in that “not all participants are equally articulate and perceptive” (Creswell & Creswell, 2018, p. 187). This may be true; however, a more significant limitation related to this study was the openness and willingness of the participants to fully disclose and deeply discuss their personal histories and identities during the interviews. Some of the participants in this study seemed more comfortable, whereas others were more guarded. This perception during the interviews was also reflected in the transcripts of each interview and the amount of talking by the researcher as compared to the participant. Despite these limitations, the findings of this study are considered credible, dependable, confirmable, and transferable.

### **Conclusion**

This study is situated within a constructivist paradigm therefore a qualitative case study methodology was adopted. Additionally, this study is a descriptive and interpretive case study of the mathematical identity of preservice teachers, in their third year of a teacher preparation

program, enrolled in a mathematics methods course in a large Midwestern university during the fall semester. The research questions for this study guided the researcher in developing an understanding of mathematical identity, perceptions of equity, and the relationship between them. Data collection methods included unstructured and semi-structured interviews as well as personal documents. The data analysis was both inductive and deductive allowing the researcher to move from a particular focus to a general focus. Throughout this study, careful attention was paid to trustworthiness to ensure the results of the study are credible, dependable, confirmable, and transferable.

## Chapter 4: Participant Results

### Data Organization

The narrative descriptions in this chapter are organized by each participant, A through H. Each section begins with a description of the externally and internally defined dimensions of identity, co-constructed through the unstructured interview, semistructured interview, and mathematics autobiography. This is followed by the description and interpretation of the data for each category: beliefs about competence and performance, beliefs about recognition, interest, perceptions of equity through salient identities, and perceptions of equity through sociocultural experiences.

### Participant A

**Externally and internally defined dimensions of identity.** Participant A identifies as a White, cisgender female, daughter, sister, girlfriend, granddaughter, and academically gifted. Participant A identifies strongly with being a teacher as she just “always knew that [she] wanted to be an educator ever since [she] was really little (interview, September 27, 2018). Both of her parents are educators and she described them as progressive. Participant A is from a midsize Midwestern city. Participant A described her core sense of self as “bossy,” strong willed, stubborn, sensitive, and emotional. She also has a strong sense of right and wrong and holds high expectations for both herself and others. Participant A believes that the way she sees herself is aligned to the way others see her. Her parents have told her she is “bossy” from the time she was little. Her mom also regularly tells her that she is sensitive to other people’s feelings and needs, a theme that emerged throughout our conversations. Participant A shared that as a high school freshman she was in an Algebra II class with seniors that previously failed Algebra II.



Empathetically, she described this experience as difficult because it was hard for her to see others struggle.

Participant A also sees herself as someone that tends to identify more with adults rather than with her peers. She shared that “even when I was in third or fourth grade when I went to sleepovers, I'd go to bed early and wake up and hang out with the parents when they were drinking coffee and reading the paper” (interview, September 27, 2018). This sense of self and connection with adults extended to school. She explained that “I always engaged more with the teachers. I always wanted to be in the teacher's classroom at lunch. I always wanted to do those things. I felt more comfortable with adults at a very young age” (interview, September 27, 2018). Participant A holds a belief that the connection she has with teachers is partially based on her academic ability stating that “I think that it's easy for teachers to like the kids that get it and so she liked me a lot” (interview, September 27, 2018). This identity has persisted through college as Participant A expressed that “I feel more comfortable, definitely, with my professors” (interview, October 26, 2018). This is a juxtaposition with the way she identifies with her peers in her cohort. Participant A shared that “in terms of the inclusivity, I definitely find myself on the outskirts” (interview, October 26, 2018). As we discussed the sociocultural dynamic within the cohort, as a means to understand this self-perception, Participant A explained that many of the women in her cohort have an identity associated with being in a sorority and described not being in sorority as a “consequential label for the rest of us is non-sorority girl” (interview, October 26, 2018). Participant A understood this difference as a matter of human nature explaining that people naturally feel comfortable with people that they have something in common with.

**Beliefs about competence and performance.** Participant A has a robust confidence related to her mathematics competence and performance sharing that “of all the subjects I think

math was probably the one I felt most confident about when I was in school” (interview, September 27, 2018). Participant A holds a belief that her academic success in mathematics is attributed to her natural ability. When asked about her earliest memory in mathematics she shared a frustrating experience from kindergarten when she had to spend time learning colors and shapes, concepts she believed she naturally understood. Participant A attributed this natural ability to a parental influence sharing that “because my dad's a middle school science teacher that stuff just kind of came naturally” (interview, September 27, 2018). In third grade Participant A was identified as gifted, in both mathematics and reading, this further contributed to her academic confidence, particularly in mathematics. In fifth grade Participant A recalled that the environment in her gifted classroom was very stressful due to the teacher’s approach with students. However, because “it still came pretty naturally to [her], [she] didn't hate the math” (interview, September 27, 2018).

Participant A also recognized that her success in mathematics is related to both her effort and the effort of her teachers. She described a sense of achievement after putting in the extra time and effort to learn something challenging. Even during times when mathematics was frustrating for her, supportive teachers, who invested in her learning, helped build and maintain her confidence. When Participant A perceived that her teachers were not interested, her confidence decreased. Unfortunately, she shared an experience about a teacher that did not invest in her learning thus creating a sense of uncertainty related to her ability to succeed in this mathematics class. Participant A described this as the worst mathematics class she had ever taken. Although she received in an A in the class, she said that she “absolutely drowned in that class” (interview, September 27, 2018). In addition, her experience left her feeling unprepared to take the AP Calculus exam; she scored a 1 out of 5 on the exam which further eroded her

confidence. When it was time to enroll in classes for her senior year, her school counselor convinced her to take Calculus II, with the same teacher, despite her concerns about being academically ready. Participant A shared that she “hated every minute of it. I knew I didn’t have the information from before. So whatever confidence I had going into that class, I had none of it left” (interview, September 27, 2018). Because of this experience, Participant A believes that she will be more competent teaching elementary and middle school mathematics rather than advanced mathematics in high school.

**Beliefs about recognition.** Participant A was identified as mathematically gifted in third grade. Although she was placed on an accelerated path, completing both Algebra I and Geometry in middle school, she did not initially see this as recognition of her mathematical ability. Participant A shared that she “knew [she] was taking something higher than the other kids but [she] didn’t know really, why or what” (interview, September 27, 2018). Later in middle school she noticed that some students were placed in an even more advanced path in mathematics and that was the first time she experienced not being recognized as the “best and the brightest” (interview, September 27, 2018).

Being recognized as mathematical was not always easy for Participant A. There were a few particular memories that Participant A shared that being recognized caused her some discomfort. One memory was a time when she was assigned to be the teacher to one of her classmates. She described the experience as frustrating because being positioned as the teacher made her peer feel uncomfortable. Additionally, she shared that just because she understood the mathematics this did not necessarily mean that she was equipped to teach someone else, especially someone she perceived as struggling. She remembered these types of experiences as hard for both her and the other student. However, she also stated that “there is a certain amount

of pride in that too, for every ounce of being singled out, there's also that "I am doing okay at this" (interview, September 27, 2018).

When asked how others see her mathematically, Participant A believes that "some of [her] peers probably think [she] is a know it all" (interview, September 27, 2018). Because of this, she currently finds herself tempering her engagement in class stating that she "definitely does not answer all the questions she could" (interview, September 27, 2018). Participant A also recognized that this perception is also dependent on context. She explained that "people who weren't in my community saw me as really good at math. People in my accelerated community were like, "She's about average," because in that community, I was" (interview, October 26, 2018). Additionally, the need to regulate other's perceptions of her is also influenced by the large number of female participants within the context.

Recognition in mathematics has been a mixed experience for Participant A. At times it has been positive, providing a sense of pride, and at other times it has been difficult, creating social challenges with peers. However, through her experiences Participant A has come to believe in the power of confidence stating that "I think that confidence is one of the best things we can help our students build" (mathematics autobiography, August 23, 2018).

**Interest.** Participant A has an interest in mathematics that began to develop at an early age, perhaps through the influence of her dad and the ease of which she excelled in mathematics. Within her beliefs about mathematics is a sense of human agency stating that in mathematics "people create a way to document and build on things that we discover" (interview, October 26, 2018). This notion was consistent with her understanding of mathematics, she explained mathematics as, "a system of concepts that we use to describe how things in the world work" (interview, October 26, 2018). She appreciates the linear aspect of mathematics and the

opportunity to look back at each step in her work, determine any errors, and to learn through this process. Participant A believes that “math should be less about the right answer and more about the right process” (mathematics autobiography, August 23, 2018). Furthermore, Participant A believes that mathematics is important in life and extends beyond the mathematics classroom. These beliefs carried Participant A through times that were challenging and frustrating. When Participant A described mathematics as hard or less fun this was attributed to her teacher at the time and not her interest in mathematics. Participant A recognized the temporal influence of her teacher’s interest in mathematics on her interest.

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant A (Appendix F). Participant A’s beliefs about competence and performance, particularly as it related to natural ability, emerged as the dominant factor in the data.

**Equity perceptions through salient identities.** Participant A is aware that her personal identities as well as her mathematical identity are shaped by her experiences. Participant A is keenly aware of the gender stereotypes and the dynamics this creates within a mathematics context. In classes that include more males, Participant A expressed that “I think it's more of this cultural idea that men want to excel, and women should just be kind of more passive” (interview, October 27, 2018). Although Participant A feels more comfortable in settings with male classmates, she also recognizes the stereotypes that her male classmates may have about females within a STEM context. She shared that “STEM things tend to lend themselves more towards male audiences and then more of those English classes I would consider those more flowery content areas and lend themselves better to where we put women” (interview, October 27, 2018). In contrast to the classes that have been more gender balanced, her classes with her elementary

education cohort are predominately female. Participant A believes that “men are more likely to say, “I am a math person.” Women are more likely to say, “I’m not a math person. I was never good at math. I’m never going to be good at math” (interview, October 27, 2018). Participant A shared a slam poetry experience that helped articulate the notion of taking up space as it related to gender and her role within a mathematics context. She shared that “as my male peers continued to take up more space, my female peers started to take up less” (interview, October 27, 2018).

Participant A believes that her various identities may cause a challenge in understanding her students’ perspectives. Participant A shared that “somebody who’s struggling with gender and sexuality. How are you supposed to have kids who are putting that stuff away when they walk in your classroom? That’s going to be hard because I haven’t faced a lot of those struggles” (interview, October 27, 2018).

**Equity perceptions through sociocultural experiences.** Based on Participant A’s experiences as a student, tracking practices are a part of her equity belief system. Participant A recognizes that in mathematics being assigned to a track has a potentially dangerous impact. However, because she was identified as gifted at such an early age and was on the advanced, accelerated path in mathematics her beliefs about tracking practices are focused on the challenges of being stuck on that path rather than the challenges of accessing the advanced path. Participant A shared that “I don’t think that it’s always inherently bad. Once you’re on that track, I think the problem part comes from when you can’t get off of it” (interview, October 27, 2018). Participant A described equity in mathematics as individualized learning that does not negatively impact a student’s self-perception. Participant A is aware that students recognize their position within a classroom when learning groups are static and organized homogeneously by perceived

ability. Participant A believes that equity in mathematics is, “doing your best to individualize stuff and hopefully not demoralize them because you're individualizing” (interview, October 27, 2018).

Throughout the data are examples that suggest that Participant A had access to a high-quality curriculum through advanced course work and gifted services. Experiences related to teaching and learning were described as both effective and ineffective, however because she reported high-levels of mathematics achievement, effective teaching and learning was likely a factor. In addition to her parents and teachers, Participant A expressed high expectations for herself. Through her experiences, Participant A’s beliefs developed over time and filter her current perceptions related to equity. Furthermore, Participant A’s perceptions of equity were predominately shaped by her academically gifted identity and her gender identity (Appendix F).

### **Participant B**

**Internally and externally defined dimensions of identity.** Participant B identifies as a White, straight female from a suburban area outside of a midsize Midwestern city. According to Participant B, others would describe her as nice, sweet, smart, funny, creative, level-headed, and patient. This is aligned to her core sense of self; however, she shared that “people think I’m a lot nicer than I am” (interview, October 22, 2018). At times in high school, her self-perception fluctuated dramatically from “feeling perfect to feeling like an idiot.” Being considered smart seems to be important, although not explicitly stated, and is aligned to a previous long-standing future identity as a medical professional. This perception has been reinforced by others telling Participant B, “you’re going to have your doctorate. You must be smart” (interview, October 1, 2018). When making the decision to pursue a career in elementary education, Participant B explained that “as a teacher, sometimes I feel like I’m looked down on. I’m not dumb. It’s

definitely hard. I know it'll be worth it" (interview, October 1, 2018). Additionally, Participant B shared an experience that happened on the day of our second interview in which she made an error during a mathematics lab and the instructor made a comment that diminished her sense of self. Although the comment by the instructor that her solution was "close" may have felt supportive to some students, Participant B's reaction was "I'm not an idiot" (interview, October 22, 2018). Participant B's former future medical professional identity is also associated with status and wealth, something she feels is important to her dad. Interestingly, Participant B did not identify her socioeconomic status when asked to describe the various externally defined dimensions of her identity.

**Beliefs about competence and performance.** One of Participant B's earliest memories is that of memorizing multiplication facts with her parents, which was hard for her. This developed into a belief about not being competent with memorizing multiplication facts and the "simple details in mathematics" (interview, October 1, 2018). This was also associated with timed tests and the frustration of "going over and over it" (interview, October 1, 2018). However, Participant B was able to adapt by "figuring it out in [her] head before each test" (interview, October 1, 2018). An example of this occurred in fifth grade when she changed schools and was given a mathematics placement test. Participant B explained that during the test she forgot the algorithm for long division and multi-digit multiplication. Instead she used an alternative method and correctly solved the problem however she was still placed in a "special math help thing" (interview, October 22, 2018). Although she was moved back to the "regular class" (interview, October 22, 2018), this was described as a negative experience.

These experiences shaped an early belief about competence and performance related to memorization; however, it did not seem to negatively shape her enduring beliefs as she also



stated, “I always did well in math” (interview, October 1, 2018). One explanation for this may be related to the influence of her dad. Participant B’s dad is a medical professional who set expectations for her mathematics success based on his success in mathematics. Through this Participant B developed a belief about natural ability. Participant B shared that “he would tell us things like, ‘You guys are all going to be good at math too.’ I think that had the placebo effect, just being told that you’re going to be good at math” (interview, October 1, 2018).

Although Participant B’s beliefs about competence and performance may have been strongly influenced by her dad’s beliefs about her mathematics ability being “in the family” (interview, October 1, 2018), she also holds a belief that learning mathematics is about practice and through practice a person becomes faster at mathematics stating that “for some people it might be harder to learn it at first, but if you practice it, you’ll just get fast with it” (interview, October 1, 2018). This belief was developed based on a comparison she made between herself and her peers. She stated that “her friends were just good at memorizing and being fast with it...and they all got straights A’s” (interview, October 1, 2018). The belief is also associated with her understanding of her academic performance in elementary school. Participant B associates not excelling in elementary school with a gap in knowing how to effectively study (memorize) and do homework rather than her ability to understand or perform in mathematics. She eventually developed these skills as she got older, stating that “you just had to learn how to study” (interview, October 1, 2018). Overall, Participant B has a strong belief in her competence to understand and perform in mathematics.

**Beliefs about recognition.** Participant B believes that others recognize her mathematical ability. Participant B shared an early memory of being recognized by a teacher in which her sixth grade teacher acknowledged her performance and suggested that she advance to Pre-Algebra.

She chose not to move classes in order to stay with her friends but later regretted her decision and advanced to Algebra when she had the opportunity again. Participant B's calculus teacher was her favorite mathematics teacher. This teacher recognized her mathematical ability by simply asking "Are you going into math?" (interview, October 22, 2018), implying she believed in her potential to be successful in a mathematics related career. Participant B expressed that "it always makes you feel so good when someone a lot older than you, like your teacher, just praises you for something" (interview, October 22, 2018). Participant B also noticed other students were being recognized for their ability in history and English and were being asked by teachers to be in the honors classes. Not being recognized made her feel bad and at that point she made the decision to be in all honors classes and then "made it happen" (interview, October 1, 2018).

Participant B also believes her peers recognize her mathematical ability, as many of her friends ask for help with mathematics homework. According to Participant B, being recognized as mathematical by her peers feels good but is tempered with not wanting to seem overconfident or annoying. This reflects her current academic environment, a cohort model with a sense of community and cooperation. Tempering her academic competence and performance was also mentioned as she described the culture of the public school she attended during her freshman year. According to Participant B, students who were too academically focused would have been labeled as a "try-hard." This changed during her sophomore year when she transferred to a private all-girls school with a competitive culture. At this school, Participant B felt like other students "looked down at you if you didn't do as well" (interview, October 22, 2018). According to Participant B, grades shape how others perceive you; describing an experience to illustrate this belief, she shared, "If I got an 82 on a test, girls would roll their eyes at me. They'd be like, 'Sorry.' It was intense" (interview, October 22, 2018). A pattern of high grades provides one

explanation as to why both her high school friends and college classmates would recognize her as mathematical. Through her interactions with teachers, classmates, and parents, as well as through grades and placement in honors mathematics classes, Participant B has come to believe that others see her as mathematical.

**Interest.** “I love math” (mathematics autobiography, August 22, 2018) is the first sentence of Participant B’s mathematics autobiography. She goes on to state that “math is one of the most important subjects to learn because it pushes students to critically think by recognizing patterns, solving word problems, etc.” (mathematics autobiography, August 22, 2018). Participant B enjoys trying to figure out how mathematics works and believes mathematics is discovered rather than created. Although Participant B describes mathematics as frustrating at times, Participant B looks forward to doing mathematics homework, as compared to reading which she finds boring.

Participant B’s interest in mathematics developed through the influence of her dad and the expectation that she would take over his medical practice someday. This future oriented identity led her to an honors course sequence in high school that included Geometry, Algebra II, Pre-Calculus, and Calculus. Participant B’s interest in mathematics was also associated with the type of status and power that is assigned to medical professionals. Despite the change in her future oriented identity from a medical professional to a teacher, Participant B’s interest in mathematics remains. However, in the future, Participant B is considering a master’s degree in mathematics or mathematics education to maintain the status associated with mathematics. Overall, Participant B has a strong interest and appreciation for mathematics.

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant B

(Appendix F). Participant B's beliefs about recognition and interest were most prominent in the data with recognition driving interest.

**Equity perceptions through salient identities.** Participant B shared that she “grew up in a bubble” (interview, October 22, 2018) and that her various identities provided opportunities for her. A diversity course that she took “opened [her] eyes to a lot of things” (interview, October 22, 2018). Participant B is in the process of understanding implicit bias related to race, culture, and gender. When asked how implicit bias might play out in mathematics, Participant B provided an example of a friend who is Asian, and the stereotypes related to ability in mathematics and the assumptions her friend has experienced that do not align to her own perceived ability.

Participant B also recognizes the role of gender stereotypes in mathematics stating, “it’s like, girls are bad at math and boys are good at math. That’s a thing” (interview, October 22, 2018). Participant B connects this to the underrepresentation of women in mathematics related fields explaining that “I think the big thing comes from that a lot of men are in engineering and doctors and those kinds of degrees, focused around math. And women aren’t as popular in those” (interview, October 22, 2018). Because of her experience in an all-girls high school, she felt empowered as a female in mathematics and “never really experienced sexism or anything like that because there was a lot of female power” (interview, October 22, 2018). Many of her former classmates are pursuing mathematics related careers, and this seems to evoke a need to challenge gender stereotypes stating that “everyone is becoming doctors, engineers, they’re going into those kinds of professions and I’m now getting out of that, like girls don’t do that. Kind of makes me want to do it now” (interview, October 22, 2018).

Although Participant B recognized stereotypes related to gender, she has never felt like she did not belong in mathematics likely due to her beliefs about natural ability and her parental

influence. However, she does believe that being a female along with being White may provide some challenges as she pursues opportunities in elementary education. Participant B believes that males and racially diverse candidates will be given preferential treatment in the hiring process. Participant B discussed the importance of a diverse workforce however, her beliefs are based on a perception that it “easier to learn from somebody that you identify with” (interview, October 22, 2018), rather than the belief that the workforce should represent and reflect the diversity of our society because it creates a richer, deeper experience.

**Equity perceptions through sociocultural experiences.** Participant B identified challenges that exist in recruiting and retaining high-quality teachers to diverse, high-poverty communities. Her current practicum experience has reinforced this sharing that “the school that I’m in now, it’s very diverse. All the teachers are White and female and they’re not the best teachers because, I think, it’s because nobody wants to work in those schools because it’s difficult” (interview, October 22, 2018). This statement suggests that she holds a belief that effective teaching and learning is a barrier to equity.

Participant B understands that equity is about providing students what they need and is working through the tension related to fairness. She believes that “equity is different from just equality. Equality is giving everybody the same thing and thinking that it’s equal. But equity is giving people who need more and more stuff... pushing everybody equally, at the levels that they’re at” (interview, October 22, 2018). Although it was not clearly articulated, Participant B was expressing the importance of high expectations for all, “pushing everybody equally” while differentiating instruction based on a student’s needs. Within this tension between equity and equality is the notion of fairness. She discussed the issue of fairness and how people perceive giving some more than others based on their needs. Participant B framed this conversation

through her family's beliefs related to politics. Participant B believes that people are generally supportive of equity in education but draw the line when it comes to issues related to how taxes are used. Participant B grappled with this contradiction and went on to explain that people have a hard time with providing more to some students based on perceptions of people living in poverty. Participant B currently holds beliefs about poverty that are related to family dynamics stating that generational poverty is due to the fact that "parents are either at work or they're drug dealers, or all your friends are. When you're a teenager, you're not thinking about a future. Especially if you're growing up surrounded by role models who don't care" (interview, October 22, 2018).

Throughout the data are examples that suggest that Participant B had access to a high-quality curriculum through advanced course work. Experiences related to teaching and learning were described as both effective and ineffective, however because she reported high-levels of mathematics achievement, effective teaching and learning was likely a factor. In addition, not only did her teachers express high expectations for her related to mathematics, so did her family. Participant B's beliefs developed over time through these experiences and filter her current perceptions related to equity. Furthermore, Participant B's perceptions of equity were predominately associated with her gender identity and racial identity. Although Participant B did not name her socioeconomic status as an externally defined identity, it was included in the conversations related to her family background and shaped her beliefs about equity (Appendix F).

### **Participant C**

**Externally and internally defined dimensions of identity.** Participant C identifies as White, female, daughter, wife, mom, volunteer, and student. Participant C is from a small rural

Midwestern town. Participant C is pursuing an elementary education degree after already completing an undergraduate degree in English and a master's degree in library science. Participant C describes her core sense of self as someone who is giving and caring, and she believes others see her that way too. This also emerged as she discussed her purpose for pursuing an elementary education degree. She explained that her community is in need of high-quality teachers that stay in the district. Her concern is that the children in the community are “stuck there by circumstances” (interview, October 22, 2018), and she is motivated to do something positive for her community that has greater meaning than her previous jobs. Participant C is a focused student with a robust work ethic, explaining that “I take things very seriously and I want to do my work, not just do the minimum, but I want it to mean something” (interview, October 22, 2018). Participant C recognizes that because of her age and experience she has a different perspective and interests as compared to her current classmates.

**Beliefs about competence and performance.** One of Participant C's earliest memories in mathematics was that of timed assessments in elementary school. She provided specific details related to this experience stating that “there was this one kid, his name was John who always got done with time to spare. Of course, he always got praised. “You're so great at this.” I'm like, “I am an idiot. This is terrible” (interview, October 3, 2018). Not only did this experience shape her belief about competence and performance, it also conflicted with her core sense of self that “[she] was a finisher” (interview, October 3, 2018). She described these experiences as being set up to fail, “after doing several of them and never completing it, it was more like dejection” (interview, October 3, 2018).

Participant C's beliefs about competence and performance persisted throughout high school and as a result she focused heavily on English rather than mathematics. She “suffered”

through Geometry class stating that “I never considered myself good at it. I really struggled with geometry and I still do . . . spatial awareness and stuff, I am terrible at it” (interview, October 3, 2018). However, because she viewed algebra as a puzzle and felt confident in her ability to solve puzzles, she seemed to have enjoyed algebra more than geometry. Even with a sense of confidence with this content, her experience was not positive due to the teacher, thus potentially eliminating the opportunity to productively shape her beliefs. She described her Algebra teacher as, “extraordinarily mean” (interview, October 3, 2018). According to Participant C, this teacher would yell at students for making mistakes and “call you out on it” (interview, October 3, 2018). This environment created anxiety for Participant C particularly on testing days, thus further developing negative beliefs about competence and performance.

Participant C “feels negative about math all the time. Mostly because of not being able to keep it in my head is frustrating. We just tested on geometry in math class and it is my nemesis” (interview, October 22, 2018). Participant C described this as not having a natural ability to do this in her head. Participant C’s beliefs about her competence and performance in mathematics are so deeply held that even when she has been successful, they created feelings of uncertainty and discomfort. In a recent experience, Participant C received positive recognition related to a mathematics assignment. When her assignment was returned it said, “full points. Outstanding. Please come see me” (interview, October 22, 2018). Because this type of success or recognition in mathematics was not typical for her, she initially thought her professor was questioning her integrity. Logically she knew that this was “the exact opposite reaction you’re supposed to have when you do well” (interview, October 22, 2018). However, she shared that if “that had been a regular paper for any other class and they’re like, ‘You got full points.’ I’d be, ‘Of course I did, because I’m amazing.’ But for math, this is a mistake” (interview, October 22, 2018). She went



on to say that when the professor “posted the grades for the second lab....and [she] got full points again, [her] first thought wasn’t, ‘Yay, me, I did it!’ It was more like, ‘I don’t deserve this’ (interview, October 22, 2018).

Participant C is fully aware of how strong her negative beliefs are related to competence and performance and currently seems to be reframing them based on the ineffective instruction she received as a young student rather than her perceived inability to understand and perform in mathematics. Participant C shared that “it hasn’t been until recently when I’ve returned to school that I’ve had teachers who finally gave math meaning” (mathematics autobiography, August 23, 2018). Further pushing her to amend her beliefs are the real-world experience with mathematics that she has had as adult. Participant C share that “the older I get the more I have to be a math person just because of the responsibilities I take on with my family or work or volunteering” (interview, October 22, 2018). Participant C is grappling with her perception of self as it relates to competence and performance in mathematics stating that “Maybe I am math person, I’m just not there yet. I liked doing a good job at it, but I hated the job itself” (interview, October 3, 2018).

**Beliefs about recognition.** Participant C does not have a strong sense of being recognized as mathematical by others. She recalled feeling jealous when the student who always finished his timed assessments was recognized. She shared that “several of us were jealous that him and a couple of other kids got pulled out to be bused over to the middle school to do math and we just had to sit there doing regular math” (interview, October 3, 2018). Not being included in this group of mathematically advanced students and by being relegated to “regular math” may have contributed to her negative beliefs about competence and performance. Further adding to the negative impact of the timed assessments was the fact that “those worksheets disappeared. I

don't remember getting a grade back. It would come back in a report card that went to my parents. I was never involved" (interview, October 3, 2018). In the absence of her teacher's feedback, Participant C's beliefs were shaped by her inability to finish a timed assessment. Participant C also believes that her children do not see her as particularly mathematical as they would "go to their dad to get help with math first, because he's very good at it mentally and he doesn't have to work as hard to come up with the answers" (interview, October 22, 2018). However, she did have a job as a bookkeeper and in that role, she was the "numbers person" (interview, October 22, 2018), a perception she was not comfortable with.

**Interest.** Throughout our conversations Participant C articulated that she does not see herself as a "math person." This is such a strong belief that she began her mathematics autobiography by stating, "I would never describe myself as a math person" (mathematics autobiography, August 23, 2018). In contrast, Participant C stated "[She] was a literacy person. [She] would just go read books and write papers and that'll be it" (interview, October 22, 2018). As a student Participant C was not interested in mathematics, and these feelings extend back to her childhood experiences with both her parents. In her family, she identifies her dad as the "math person" and her mom as the "literacy person." The memories she shared related to experiences with her dad that involved mathematics were not positive. Her dad made her feel that "because [she] wasn't instantly great at it, it was more like, 'Well, you're struggling, so therefore I'm going take over, because I can see that you are just not interested in struggling through it. You're wanting to give up'" (interview, October 22, 2018). This memory is in stark contrast to the memories she described with her mom related to literacy. Participant C and her mom, a former kindergarten teacher, shared a love for reading and going to the library. Participant C stated that mathematics, "feels very much like spreadsheets and data and

interpretation or research, which all sound like work to me” (interview, October 22, 2018).

Participant C compared doing mathematics to going to the gym whereas reading was described as a relaxing activity.

In high school Participant C’s effort was directly related to her interest as well as her beliefs about competence and performance. She recalled hating Geometry because it was confusing and did not have a real-world application, sharing that “I didn’t want anything to do with that. I tuned out and I didn’t do my homework. I just suffered through that class” (interview, October 3, 2018). In addition, Participant C did not recognize an interest on behalf of her teacher stating that “Geometry was a disaster. He was near retirement and it didn’t feel like he cared to push us. It was like, Well, we’re all in this room together. So, you either do it or you don’t” (interview, October 3, 2018). This perception that the teachers were uninterested extended to the entire mathematics department with the exception of one teacher. Again, in contrast to her experiences and perceptions related to literacy. Participant C shared that “my junior year English teacher was amazing, and I loved her very much. I think I kept going with English because of her” (interview, October 3, 2018).

Participant C’s lack of interest may also be due to the misalignment in her beliefs about mathematics and her experiences as a learner. Participant C believes that mathematics is discovered rather than created and the purpose of mathematics is “to solve your problems. It’s supposed to be a tool to make things make sense and make it easier for you” (interview, October 22, 2018). According to Participant C, “math doesn’t just have to be limited to a test on a piece of paper. It is supposed to make your life easier in all realms” (interview, October 22, 2018). However, the experiences she described as a learner did not include opportunities for deep conceptual understanding or application to the real world. Participant C shared that “we didn’t do

strategies. We did memorization” (interview, October 3, 2018). Further elaborating on this, Participant C shared that “there were no drawing pictures, there was no trying to conceptualize it in multiple ways. It was, ‘This is how you do math. It either goes this way or this way.’ It was not exciting. It wasn’t interesting” (interview, October 3, 2018).

As Participant C prepares to become an elementary educator, her interest and effort in mathematics have increased because of her strong desire to be an effective teacher. She is concerned that students will, “get a great foundation in literacy and struggle with math their whole life because in my year they didn’t get an adequate math education” (interview, October 3, 2018).

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant C (Appendix F). Participant C’s beliefs about competence and performance and interest were most prominent in the data, particularly as it related to the comparison between mathematics and literacy.

**Equity perceptions through salient identities.** Participant C’s salient identity is associated with literacy rather than mathematics therefore she has a sense that she only “somewhat” (interview, October 22, 2018) belongs in mathematics. When asked if this is related to her perceptions about gender in mathematics, she rejected this notion but felt it was related to her beliefs about competence and performance and her strong sense of belonging in literacy. Participant C is keenly aware that her fragile mathematical identity could create a barrier for equitable experiences for her future students. Participant C described a desire to focus on mathematics in her teacher preparation program because she sees the teacher as the “conduit for all knowledge” (interview, October 22, 2018).

Participant C has a multifaceted understanding of equity in mathematics, which is framed through the community in which she lives. Although participant C did not explicitly identify a geographic marker as one of her many identities, she did discuss being a member of a rural community and her future oriented identity is associated with becoming a teacher in a rural community. Participant C shared that there is a “deficit in [her] community of good teachers and they keep leaving because the school district does not pay them enough to make them stay” (interview, October 22, 2018). Furthermore, Participant C described the inequities this creates for students to receive consistent effective teaching and learning experiences within the same school.

**Equity perceptions through sociocultural experiences.** Access to effective teaching and learning practices emerged as we discussed a personal experience with one of her friend’s children. Based on her observations and conversations with other parents, she believes that each class is receiving differential, inequitable learning opportunities based on the individual teacher’s instructional approach. Participant C suggests that one of the teachers is not effectively differentiating instruction based on the student’s current understanding. Participant C believes the goal of differentiated instruction is to “give them a way to see it or the tools to work through it, so that everybody comes out on the other side with the same level of ability” (interview, October 22, 2018). Embedded within Participant C’s understanding of equity is the notion of same. There is an essence of education being the “great equalizer” for students within her discussion of equity in mathematics. Although it was not precisely communicated, the essence of Participant C’s beliefs is that equitable access means that students have the same opportunity to experience effective teaching and learning. Within this is the notion that there are multiple ways to solve a problem and that mathematics is more than memorization. This current belief is rooted in her past experience as a student sharing that “we didn’t do strategies, we did memorization”

(Participant, October 3, 2018). Participant C attributes the ineffective teaching and learning practices she experienced as a learner to her current beliefs about competence and performance and interest.

Participant C explored some of the more complex issues associated with equity as she discussed the lack of power students have to change or increase their opportunities. Participant C shared that “children are underage, they’re not adults. They don’t really get a vote in their existence. They can’t move to a better school district by themselves. [They] are not given the power to change their own circumstance” (interview, October 22, 2018). The lack of opportunity for some students in her community is also related to limited housing and jobs and the financial means of their families. According to Participant C, “there’s no reason to come to [her community] because [you] won’t get a job or a tax break” (interview, October 22, 2018). If families have the financial means to leave the district they do, “and so the kids who are there and stay, are because they can’t go anywhere else. The families that do have the money and the ability to go elsewhere usually do” (interview, October 22, 2018).

Throughout the data are examples that suggest that Participant C did not had access to a high-quality curriculum in mathematics. Experiences related to teaching and learning were consistently described as ineffective. Participant C did not describe experiences that included others having high expectations for her. Instead, it seemed as if this was a void that was filled by negative beliefs her about competence and performance. Participant C’s beliefs developed over time through these experiences and filter her current perceptions related to equity. Participant C’s perceptions of equity were predominately associated with her future oriented teacher identity, fragile mathematical identity, literacy identity, and geographic marker identity (Appendix F).

### Participant D

**Externally and internally defined dimensions of identity.** Participant D is from a suburb outside of a large Midwestern city. Because she is an out-of-state student at a university where the majority of students are residents of the state, she holds a geographic identity marker that she attributes to the culture of the city. Another salient identity for Participant D is related to being Catholic: “I’m Catholic. That’s a big, huge part of who I am. That’s also grown over the past three years, as far as how I apply it in my life. I think that’s a huge part of who I am” (interview, November 6, 2018). Participant D identifies as a female, sharing that “I identify with a lot of female attributes.... I do have a lot of the naturally female instincts and needs” (interview, November 6, 2018).

Participant D also discussed her future-oriented teacher identity stating that “I’ve always wanted to be a teacher. From when I was a kid playing school, I was always the teacher. I like leading people” (interview, October 1, 2018). Participant D described a teacher culture that is associated with her teacher identity sharing that “there’s this teacher culture with kids and you’re a kid person. I babysit all the time and that’s a big part of my identity” (interview, November 6, 2018). When asked to describe her core sense of self, Participant D shared that she is easy going but also “stick[s] to [her] guns” (interview, November 6, 2018). She sees herself as inclusive and supportive of others. Participant D believes that others would describe her in the same way. In addition, her family would describe her as “goofy, an out of the box thinker, and willing to try new stuff all the time” (interview, November 6, 2018).

**Beliefs about competence and performance.** Participant D’s beliefs about competence and performance have been shaped by her beliefs about mathematics, recognition related to assessment, and the sociocultural context. Participant D’s beliefs about competence and

performance may be related to a misconception in mathematics about speed and problem solving. In addition, Participant D also holds a strong belief that mathematics teaching and learning should be fun, sharing that “how much they enjoy it really determines how quickly they’ll get there” (interview, October 1, 2018). Participant D recalled many fun experiences in mathematics that included projects, chants, songs, and movement. Mathematics classes that were not fun diminished her confidence. In addition, Participant D’s beliefs about fun and confidence in mathematics are also related to the social dynamic in the classroom. In classes with friends, she performed better sharing that “it was a lot easier for me to do homework and be in class when I was with my friends” (interview, October 1, 2018). Participant D’s competence and performance was negatively impacted in situations that did not include friends.

Participant D’s beliefs about competence and performance were also influenced by various assessments and was a point of confusion for her at times. Participant D shared that, “on placement tests [she] would do really well...it just didn’t line up with other [classroom assessments]. [She] was really confused, because nothing lined up and nobody tried to figure out where it didn’t line up” (interview, October 1, 2018). Prior to being placed in the advanced path in high school she believed that “it was really frustrating to feel stuck in that, but then do really well in placement tests, and I just didn’t understand. I felt like I was just bad at math, but I could have done more with it” (interview, October 1, 2018). Although Participant D did not explicitly state that mathematics competence and performance is due to natural ability in mathematics, she commented several times that in high school “it just clicked” (interview, October 1, 2018), implying that learning mathematics was not due to effort.

Even after being placed on the advanced path, Participant D’s beliefs about her competence and performance in mathematics were influenced heavily by the teacher. She



described an experience her freshman year that included a teacher that “just didn’t care or want her there” (interview, October 1, 2018) and because of this experience it created stress and made her “feel stupid” (interview, October 1, 2018). Eventually she moved out of the advanced path to her grade level class. Although moving “down” to the other class may have decreased some students’ confidence, this experience seemed to increase Participant D’s beliefs about competence and performance. “I started going into a geometry class, and she’s going over things that we already did, so I was ahead in that class, so I just felt really confident. I was just flying through it, getting A’s on all the tests” (interview, October 1, 2018). This further suggests the influence of assessments on her beliefs about competence and performance. Additionally, Participant D’s geometry teacher positively shaped her beliefs because she perceived that her teacher had confidence in her. She shared that “she knew I knew what I was doing, so she would ask me questions. I just felt like for the first time that I really knew what was going on and I was the student that was ahead” (interview, October 1, 2018).

**Beliefs about recognition.** For Participant D, recognition has been a point of confusion throughout her experiences in mathematics, thus creating a relationship with mathematics that is clearly situated and dynamic. She believes that in class she was “pinned as not being the brightest” (interview, October 1, 2018); however, when entering high school, she was “placed in the highest math” (interview, October 1, 2018). Even through this recognition, she felt as if her teacher thought she was “hopeless” (interview, October 1, 2018). However, she acknowledged that this was more about him and the pace of instruction than about her, and she was happy to move to the middle-level mathematics class. Participant D shared a positive memory from high school where she felt recognized as the “smart person in the class” because she “understood a lot more than the people she was with” (interview, November 6, 2018). This underscores the

relationship between the perceptions of others and the perception of self. Participant D finally felt smart because she was recognized by her teacher. Inconsistent recognition has been a theme throughout her experiences. Currently, Participant D does not believe that others within her current context recognize her as a mathematical person. Participant D shared that being mathematical it not “what jumps to mind when they think about me. I’ve told my friends I like teaching math because it clicks for me” (interview, November 6, 2018).

**Interest.** Participant D’s interest in mathematics is related to her beliefs about mathematics, her future-oriented identity, and the perceived interest level of the teacher. Participant D believes that mathematics is useful, uniform, consistent, and definite and at times she considers mathematics boring. Participant D compared her interest and beliefs about mathematics to literacy, stating that “I hate reading. It’s not my thing. It’s too interpretive and I’m not like that. I’m very black and white” (interview, November 6, 2018). She further elaborated, “I just didn’t like reading from the get-go. That’s why I like math because it made sense once it clicked. It doesn’t change. It’s not like grammar where it could be this or it could be that. It’s really straightforward” (interview, November 6, 2018). This aligns with Participant D’s belief that mathematics is discovered rather than created, sharing that “I think it was discovered because it’s definite answers versus language where it’s kind of like something that was created” (interview, November 6, 2018).

Participant D holds a strong belief that mathematics teaching and learning should be fun. During middle school Participant D’s teacher dressed up as a princess to teach the three main functions in trigonometry. She described this experience as fun and helpful. This belief that teaching and learning should be fun and whimsical to be effective was also reflected in the lessons she co-developed during her practicum experience. Participant D was excited about this

lesson stating that “I love hands-on stuff and activities.... We’re going to dress up and have music going and stuff, it’ll be really cool. (interview, October 1, 2018).

Participant D’s interest in mathematics is also associated with relevance and her future-oriented identity as a teacher. Participant D shared that her interest in mathematics has increased in college because it is related to her major and because of that she enjoys mathematics more now than she did in high school. Not only is her interest related to relevance, it is also related to the perceived interest of the teacher. She believes that “the teachers now, they’re more into it” (interview, November 6, 2018), thus creating an enjoyable experience and increasing interest. In elementary school it was more important to be in the classroom with the teacher she believed “loved everything” (interview, October 1, 2018) rather than to be in advanced mathematics. Participant D explained that the other students “were really excited to be in advanced math, I could’ve cared less, to be honest it was just like whatever, cool, because I enjoyed the class I was in for math” (interview, October 1, 2018).

Participant D’s interest in mathematics decreased during her College Algebra class due to the lack of interest of the teacher. She shared that, the teacher would tell them “‘I don’t want to be here. I was supposed to be an engineering major, and it didn’t work out, so here I am.’ I was mad.... I didn’t want to be in it” (interview, October 1, 2018). Participant D’s negative experiences with her College Algebra teacher and her positive experience with her Geometry teacher shaped an enduring interest in geometry over algebra sharing that “I still love geometry. I don’t like algebra” (interview, October 1, 2018). Although Participant D’s Geometry teacher was a positive influence, she did not identify her as a role model and did not strongly identify anyone in her life this way.

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant D (Appendix F). Interest was the most prominent factor in the data for Participant D, particularly as it related to beliefs about mathematics and the interest of the teacher.

**Perceptions of equity through salient identities.** Participant D identifies as female and holds beliefs about gender differences that shape the way she perceives the dynamics within the sociocultural context. Participant D believes that females are naturally more confident than males, however, she also believes that females are more comfortable engaging in all-female classes. Within the current predominantly female teacher education cohort, Participant D suggested that there is tension between a few students and the larger group because of the perceived confidence of these few students related to their future-oriented teacher identity. Participant D shared that “if someone acts like they’re above someone else, it’s not because of their social status, it’s because they think they’re going to be more successful as a teacher and are so much smarter than us” (interview, November 6, 2018).

Participant D also expressed a salient religious identity which is reflected in her perception of a student she worked closely with during her practicum experience. Participant D belongs to the Catholic church and assumed the student she worked with during her practicum was also Catholic because, “he talks about God all the time” (interview, November 6, 2018).

**Equity perceptions through sociocultural experiences.** Participant D believes that everyone belongs in mathematics and that it is a unifying subject because the language of mathematics is consistent. Although her sentiment was focused on how mathematics creates connections between people, Participant D framed this belief through the lens of language suggesting that challenges do not exist in mathematics because, “four is four, six is six. They

don't have to worry about speech things and how they pronounce and their fluency" (interview, November 6, 2018).

Participant D's experience with learning multiplication using the lattice method is reflected in the way she views differentiated instruction. Participant D understands that equity not only means providing students the opportunity to solve problems using varied solution methods, she also understands that equity also means some students need and deserve more. Additionally, Participant D has an awareness of the issues related to grouping practices that have the potential for creating a hierarchy within mathematics. She described heterogeneous groups as providing a sense of freedom and creating opportunities for students "to relate with each other and work together in a way that doesn't single out the advanced kids and make the kids that aren't those kids feel any less. But also has chance to do the opposite too" (interview, November 6, 2018). In her practicum experience Participant D shared that the teacher grouped students by perceived like ability, and the students were aware of this because of the teacher's comments. "They know the lower and higher groups. At least for reading, when the teacher wants me to work with a group, she's like, 'Oh, you really need to work extra with them.' She'll say those things out loud. And I'm just like, 'Wow'" (interview, November 6, 2018). This has caused frustration for Participant D because she understands that being labeled a certain type of learner has an enduring impact on a student's self-perception.

Although Participant D has a sense of the inequities that can occur through grouping practices, she did not have this same awareness related to tracking practices. Participant D described being tracked in mathematics as early as fourth grade. Through these experiences she developed a belief about tracking practices and future socioeconomic status. She described this perception as if the hierarchy that is established through tracking practices is simply meant to be.

Participant D shared that “the high honors kids were really smart for the most part...they were mostly going into the harder majors—a lot of money type of business majors.... I think everyone understood that you were where you were supposed to be” (interview, November 6, 2018).

Participant D shared that throughout her school experience she was aware of her teacher’s beliefs about her and had been “pinned” as a certain type of student. Although she scored well on placement tests, it was the beliefs of her teachers that seemed to make the most significant impact on her mathematical identity. Because of her own experiences, it was important to Participant D that her practicum students receive positive verbal feedback. “When I work with them, I just really build them up with compliments and fill them up with making them feel good” (interview, November 8, 2018).

Throughout the data are examples that suggest that Participant D had inconsistent access to a high-quality curriculum in mathematics. Experiences related to effective teaching and learning were consistently described as both effective and ineffective. Participant D did not describe experiences that included others having high expectations for her. Participant D’s beliefs developed over time through these experiences and filter her current perceptions related to equity. Participant D’s perceptions of equity were predominately associated with her gender identity, future oriented teacher identity, and religious identity (Appendix F).

### **Participant E**

**Externally and internally defined dimensions of identity.** Participant E identifies as a White female from a small Midwestern town. She is a daughter, sister, aunt, Christian, sorority member, and dance team member. She sees herself as “a decent student but [she] wouldn’t say [she’s] super intelligent” (interview, October 22, 2018). When asked to describe her core self of sense, Participant E shared that “I feel like I’m a friendly person to others, and I feel like I’m

someone that a lot of people know they can come to. I can be kind of crazy and fun. There's just a lot of sides to me" (interview, October 22, 2018). Participant E also shared that she can be very shy, and when she is in uncomfortable situations, nervous, or with people she does not know, she shuts down. However, she also shared that "when I'm surrounded by love, I'm a hoot" (interview, October 22, 2018).

**Beliefs about competence and performance.** Participant E began her mathematics autobiography by stating, "I feel like math is definitely my best subject as a student. I have enjoyed learning math my entire life and have always been good at it" (mathematics autobiography, August 22, 2018). Participant E believes that mathematics does not necessarily come easy for her but is successful because of effort. Participant E attributes her confidence to being able to figure out how to solve problems using her own methods. This confidence in her ability to solve problems has created a sense of agency within mathematics. Additionally, Participant E recognizes that she "had teachers who really thought it was important to tell us the why about math, and so that really helps me also" (interview, October 3, 2018).

Participant E's confidence continued throughout her K–12 experience until her senior year Calculus class. The lack of interest by her teacher diminished her confidence in mathematics. She recalled this experience stating that "I was really crushed because I thought I could do math classes pretty well, and I did pre-Calculus pretty well. So, at the time I was like, wow, Calculus is just way too much for me. It's over my head" (interview, October 22, 2018). Confidence was a strong theme throughout our conversations. "It all comes back to being confident in yourself, and knowing what you're good at, what you're not good at, but also, not downplaying yourself" (interview, October 22, 2018). Additionally, Participant E compared her confidence in mathematics to her confidence as a writer sharing that "I just don't have

confidence in it, and I think it's because it goes back to the thing of where in math there's always ways to get this one answer" (interview, October 22, 2018)

**Beliefs about recognition.** Being recognized in mathematics was not a strong theme during the discussions we had about her mathematics experiences. Insight to this finding may be gleaned through Participant E's core sense of self. Participant E shared that "I don't feel like I need to express everything that happens in my life to people" (interview, October 22, 2018). In addition to being somewhat private, Participant E also considers herself to be shy and cautious in uncomfortable situations, which may have been how she was feeling during our conversations. Also, for someone who considers herself to be humble, expressing recognition may simply be uncomfortable to discuss. Participant E was placed in an advanced track for mathematics in middle school but did not recall taking a placement test. She did recall that there "were people in Pre-Algebra and people in regular math" (interview, October 3, 2018). In high school she took Advanced Placement classes stating that "we were all kind of on the same track" (interview, October 3, 2018).

Recognition by others occurs in different ways in mathematics. One primary means is through the explicit and implicit messages that students receive during classroom discussions. Although Participant E tends to be confident in mathematics based on her ability to solve problems, she is not comfortable sharing her thinking in large groups stating that "I'm not sure if this answer is correct because maybe I didn't get there the same way that another student got there, but also, I'm not really into drawing attention to myself" (interview, October 22, 2018). This is an interesting dichotomy as Participant E is also a dance team member and regularly performs in front of large crowds, perhaps the team aspect of dance provides a sense of comfort. Additionally, Participant E tends to regulate her participation, as a way of managing the



perceptions of others as she shared that “I don’t really come off as a nerd....I feel like I’m kind of maybe humble about it.... I’m not out there about it” (interview, October 22, 2018).

Participant E feels more comfortable and confident sharing in small groups rather than in large-group discussions.

Another means for recognition within a mathematics context is by being asked for help by peers. Because Participant E is “not out there about it . . . people don’t necessarily come to [her] for math questions” (interview, October 22, 2018). Participant E shared that she “is not out there making sure everybody knows what [she] knows” (interview, October 22, 2018).

Participant E had a vivid memory of recognition in high school, an experience that solidified her beliefs about competence and performance in mathematics. She shared that her Geometry teacher asked her to be Teaching Assistant and because of this Participant E felt as if, “she must think I really know what I’m doing” (interview, October 3, 2018). Participant E recalls “bragging to her mom” (interview, October 3, 2018) about this experience. For a humble person, sharing this type of recognition feels like bragging.

**Interest.** Participant E has always enjoyed mathematics and “pushing [herself] to figure out the answer. It does not come easy to [her] but [she] likes to figure it out and [she] feels accomplished once [she] does” (mathematics autobiography, August 22, 2018). This interest is aligned to her beliefs about mathematics, describing it “as using equations and numbers to figure out problems . . . you use math every day without even realizing it . . . it makes life make sense” (interview, August 22, 2018). Participant E believes that mathematics creates connections between people because, “there is no language difference, it is the same everywhere you go and that has stuck with me ever since. I thought that was so beautiful and it made me want to learn math more and be better at it” (mathematics autobiography, August 22, 2018). Although this

belief does not touch on the language, culture, and context that is required for sense making, the essence of her belief was that mathematics is a human practice that we are all connected to and through.

Participant E has a strong connection with her older sister through mathematics. Her sister is an elementary teacher who also holds a minor in mathematics. Participant E described this important relationship stating that “I’ll probably bring her up a lot. She’s a huge role model to me, but she’s ten years older, so she’s like a second mom” (interview, October 3, 2018). The support and the connection with Participant E’s sister also contributed to her sustained interest in mathematics even when mathematics was challenging for her. Participant E shared that “I remember struggling in eighth grade with Pre-Algebra.... that’s another reason why I liked math also, because she helped me figure it out. She pushed me to help me figure it out” (interview, October 3, 2018).

In high school, Participant E successfully moved through an advanced path, Geometry, Algebra II, and Pre-Calculus, and then she faced a challenge in Calculus her senior year. This challenge was not necessarily related to the content but to the way she felt about her teacher. Because Participant E’s interest in mathematics is related to the connections she feels, it is not surprising that she eventually dropped Calculus in high school due to a lack of connection with her teacher and therefore a lack of connection to Calculus. Participant E assumed that she would have a connection with her Calculus teacher because he was her brother’s golf coach. This disconnect was troubling. She shared that “oh this is really weird because my brother had him in class, and he loved my brother. He was my brother’s golf coach, and I was like, ‘Oh, maybe he’ll like me’” (interview, October 22, 2018). Because the teacher did not engage with her, she felt as

if there was something wrong with her and because of that she “lost all motivation” (interview, October 22, 2018) and transferred out of Calculus.

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant E (Appendix F). Interest was the most prominent factor in the data for Participant E, particularly as it related to beliefs about mathematics.

**Perceptions of equity through salient identities.** Participant E named several identities however, none of these identities were a dominant focus within the data. In a general sense, Participant E discussed that who she is shapes her beliefs and influences how she engages within a sociocultural context. Additionally, she mentioned that her identities will also shape her students’ perceptions of her which suggested a broader understanding of the sociocultural dynamics. To manage the perceptions of her students she suggested enacting a “neutral” identity.

**Perceptions of equity through sociocultural experiences.** Participant E discussed the community in which she grew up in as diverse. However, the advanced mathematics classes that she was enrolled in did not reflect the diversity of her school or community. Apologetically, she stated that “it was mainly all of the White students in the higher classes” (interview, October 3, 2018). Participant E recognizes this inequity sharing that “it’s hard. You don’t want to push them into classes that they’re not prepared for, but also it’s kind of like building a wall” (interview, October 3, 2018).

Participant E understands that this is a result of an opportunity gap within her community and a function of socioeconomics, stating that “the low SES students and diverse students are in the same elementary schools. They’re all progressing at the same rate. When we get to high school, we’re all at different levels. (interview, October 22, 2018). Participant E also associated

this variation in achievement levels with a lack of family “support at home and family lives” (interview, October 22, 2018). Interestingly, she experienced the benefits of heterogenous groups in her practicum experience. She described this school as a “trauma school” where many of the students and their families are managing challenging issues. In this practicum class there was a balance of students who had experienced Prekindergarten and those who had not. She noticed that the teacher engaged the students in the same learning experiences and that benefited all of the students in the group, regardless of their previous experience or perceived ability. She contrasted this experience with the other Kindergarten class in this school. This class was mainly students who did not attend Prekindergarten. Participant E felt that this class was not progressing in the same way and attributed it to the homogenous nature of the group. This belief about the detrimental effects of static homogenous grouping is also reflected in her response as she pledged that she “will not do groups because I feel like it’s important for them to be exposed to all of these ways” (interview, October 22, 2018). Within this lies the tension between effective differentiated instruction and ineffective grouping practices. Furthermore, as a learner, Participant E was empowered to solve problems through various solution methods, a reflection of effective teaching and learning practices. Because of this, Participant E believes that this will influence how she will teach mathematics as well as all subjects because she believes that multiple perspectives are important.

Throughout the data are examples that suggest that Participant E had consistent access to a high-quality curriculum in mathematics. Experiences related to effective teaching and learning were consistently described as effective. Participant E did describe experiences that included others having high expectations of her. Participant E’s beliefs developed over time through these experiences and filter her current perceptions related to equity. Participant E’s perceptions of

equity were predominately associated with her experiences rather than her salient identities (Appendix F).

### **Participant F**

**Externally and internally defined dimensions of identity.** Participant F identifies as a White female from a midsized Midwestern city. She is the daughter of educators. Participant F has held a future-oriented teacher identity from the time she was very young stating that “I always knew I wanted to be a teacher, from the first day of kindergarten, I just loved it” (interview, October 3, 2018). Becoming a middle school mathematics teacher has also been an interest due to her dad, a former mathematics teacher, sharing with her that there is an ongoing need for high-quality mathematics teachers.

According to Participant F, others would describe her as outgoing, hard-working, organized, and very dedicated. Participant F would describe herself in the same way; however, at times it is hard for her to accept the compliments of others when they have recognized these strengths. Participant F would also describe herself as flexible and giving stating, “I do a lot in the community, services and things” (interview, October 3, 2018). In addition, Participant F identifies as a goal-driven person and relates this characteristic to her elementary school’s data practices of having students keep a data notebook to monitor personal goals based on academic proficiency. Within this goal-driven sense of self, there is also a sense of agency. As a junior in the teacher education program, Participant F has already begun teaching as she pursued and received a substitute teaching certificate.

**Beliefs about competence and performance.** Participant F holds positive beliefs related to her competence and performance in mathematics. One of her earliest memories in mathematics is the success she experienced in first grade with timed assessments. Not only was

Participant F able to monitor to her progress as she quickly moved through the various assessment levels, it also provided a benchmark as she compared her progress to the progress of others.

For many students their beliefs about competence and performance develop not only from formative and summative assessment feedback over time but also through peer comparisons within the sociocultural dynamics of the mathematics classroom. Participant F referenced this as she described her experience with timed assessments. Participant F shared that “I know for other kids they were always stuck at something for six weeks and you could just see ‘I’m at the 12s now and you’re still at the 6s.’ You get the rush like I’ve got to do it” (interview, October 3, 2018). In elementary school these types of peer comparisons increased confidence and in high school they maintained her confidence. Participant F was in the advanced mathematics track in high school with other students she considered to be smarter than her. Noticing those students struggle with the content that was challenging for her too provided a sense of comfort. This interplay between how people see themselves, how they see others, and how others see them is evident as Participant F described her experiences in college mathematics explaining that “I saw myself more in the top tier, because I would see other people struggling with things that I personally didn’t struggle with. I became more confident, and then that’s how people maybe saw that I was good at math” (interview, October 22, 2018).

Beliefs about performance and competence are also associated with persistence. Participant F attributed her ability to persevere through challenges in mathematics through practice and the progression of learning over time. This may be related to her core sense of self as goal driven, but it also may be associated with monitoring and analyzing her own progress through data binders, a practice she learned and experienced at an early age. Further contributing

to this belief about competence and performance are her beliefs about grades that were reinforced by her parents' expectations related to effort. Her parents expected that "[she] did [her] best.... if [her] best work was a C or a B, it didn't matter, but if [she] didn't try and it was a C, then they were disappointed" (interview, October 22, 2018).

Participant F's beliefs about competence and performance related to effort also are associated with her beliefs about intelligence. Participant F believes that intelligence "plays a little bit, but I think it's more of persevering and working until you get it. Because I think that's how you build your intelligence" (interview, October 22, 2018).

**Beliefs about recognition.** Participant F believes others see her as mathematically competent. Participant F described this as a strange phenomenon that occurs sharing that "people (say), 'You're good at math.' But I've never talked to them about math before. Maybe it's because I'm good at other things, too, so they just assume that that carries over in math" (interview, October 22, 2018).

Participant F shared that her performance with the timed assessments was not only a formal recognition for her personally, but this process also created a dynamic of recognition within the mathematics classroom. She shared that "you kind of knew everyone was getting different tests because the teacher would walk around with files in a bucket and be like "okay, last week you passed your 10s" (interview, October 3, 2018). Participant F also identified that the mathematics instructional groups in her elementary classroom were based on skill or need, further providing a sense of formal and informal recognition.

In addition, when Participant F was in fourth grade, she participated in the school Math Bee, placing third or fourth. She described the student who placed first as the "smartest kid . . . everyone kind of knew he was going to win" (interview, October 3, 2018). Participant F also

stated that the Math Bee “kind of showed if you’re not good at math” (interview, October 3, 2018).

Likewise, the course sequence she was assigned to in middle school and high school was a positive form of recognition for Participant F. Participant F described the complex relationship between tracking practices, beliefs about competence and performance, and recognition. She felt as though she “had some friends who probably could have done it...[but] something happened to get them off the track and they couldn’t get back on. You knew if you weren’t on it [and] kids knew, “I’m not the best” (interview, October 22, 2018).

**Interest.** “To say mathematics was important to [her] education would be an understatement” (mathematics autobiography, August 23, 2018). Participant F has a strong interest in mathematics which may be attributed to her dad’s influence as a mathematics teacher. It also may be related to her beliefs about mathematics. Participant F believes that mathematics is about “problem solving, not just numbers and how you can manipulate them. . . it expands your horizons” (interview, October 22, 2018). Participant F sees mathematics as a vehicle for “higher order thinking . . . that helps the brain grow and stretch in new ways” (mathematics autobiography, August 23, 2018). Additionally, Participant F believes there is an alignment between her core sense of self, being an organized person, and her beliefs about mathematics, sharing that “I am very organized, and so I guess math for me is very linear” (interview, October 22, 2018).

Participant F’s interest in mathematics is associated with her beliefs about competence and performance: “I’m pretty good at math. I like it. I enjoy it” (interview, October 22, 2018). When expanding upon her interest in mathematics, Participant F compared it to reading comprehension sharing that “people really like reading, but I don’t like reading. Math has



generally one correct answer. That is really satisfying to me. Reading is good, but with reading anything will work sometimes” (interview, October 22, 2018).

Participant F seems to have a keen awareness of the sociocultural dynamics within a classroom; therefore, it is not surprising that she associates her interest in mathematics or particular content in relation to the perceived interest of the teacher. Participant F shared that “it wasn’t hard, and the teacher wasn’t very into it” (interview, October 3, 2018). She further elaborated on this point stating that “there were not positive vibes coming from middle school math” (interview, October 22, 2018). In eighth grade, Participant F recalled that the other team had a mathematics teacher that the students “loved and praised” (interview, October 22, 2018), and because of that “were all into it” (interview, October 22, 2018). This same sentiment was reflected in her description of another mathematics experience where two sections of the same course were being taught at the same time. The teachers for each of these classes were perceived differently by the students. These perceptions created a contrast in their experience; “they loved the class with one, but then others didn’t like their instructor, so they dreaded going” (interview, October 3, 2018).

Even when mathematics was challenging the interest and passion of the teacher sustained her interest and further contributed to her beliefs about competence and performance. Participant F shared that the advanced mathematics courses in high school “were [her] hardest math classes, but [her] favorite. The teachers [she] had showed a deep passion for math and a strong commitment to making sure all of their students understood the material” (mathematics autobiography, August 23, 2018).

Further contributing to Participant F’s interest in mathematics is her future-oriented identity as a middle school mathematics teacher. This identity was influenced by her dad, a

mathematics teacher, who discussed with her the need for effective mathematics teachers. Prior to being admitted to the education program, Participant F took an advanced course in mathematics in preparation.

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant F (Appendix F). All three factors were prominent in the data for Participant F.

**Perceptions of equity through salient identities.** Participant F's understanding of her personal identities and her lived experiences have developed an awareness of many complex issues related to equity in mathematics. Participant F described how her identities have influenced her perceptions of equity in mathematics sharing that "I definitely identify female. I don't think about race on a day to day basis. I think about other people's race and how their life has gotten them where they are, more than I think about mine (interview, October 22, 2018). In particular Participant F focused on her perceptions of gender within mathematics sharing that "girls can do the same things that boys can do. Math is not like a sport.... Everyone's on an equal playing field" (interview, October 22, 2018).

Participant F noted that in her Calculus class the majority of the students were male and "there was not a single minority" (interview, October 22, 2018). Participant F rejects racial stereotypes as means to understanding the lack of diversity within her Calculus class and instead explained it related to a developed understanding of the opportunity gap and different expectations for students. Participant F described the inequity of low expectations as it relates to students receiving assistance for meals at school. She noticed that in her advanced mathematics courses students who were perceived as having low socioeconomic status were not represented in these classes. She attributed this to low expectations and the detrimental effect of comfort

feedback. Participant F's awareness and understanding of the complex notion of implicit bias is reflected in her observations in her practicum experience. She observed that the teacher was keenly aware of each student's socioeconomic status and treated students differently on the basis of this perception. The teacher seemed to have higher expectations for a student of a doctor as compared to a student of a minimum wage worker.

In addition, Participants F's future-oriented identity of becoming a middle school mathematics teacher is related to issues of equity. Because her dad, a mathematics teacher and high school principal, discussed the need for highly effective mathematics teachers, this became her focus.

**Perceptions of equity through sociocultural experiences.** As she discussed her experiences in mathematics, Participant F recognized that tracking is not an equity-based practice. Participant F acknowledged that tracking practices create opportunity gaps for students to access advanced level mathematics in high school. Participant F discussed how this opportunity gap continues later in life sharing that "I don't want to say not having calculus is going to cut you way back, but you're just kind of always that one step behind. You can't get in to where you need to be, once things are predetermined" (interview, October 22, 2018). The notion of "predetermined" evokes a sense oppression that unfairly prevents people from becoming mathematical and diminishes the opportunities and benefits associated with that. Participant F described equity in mathematics as having the same high expectations for achieving the learning outcomes for all students and achieving that through effective differentiated learning experiences and not through tracking practices.

Participant F believes that the level of rigor was not substantially different within the accelerated mathematics path in her high school and, in fact, she believed it was less so in certain

situations. Participant F's awareness of the detrimental effects of this type of tracking are based on her own experiences but also based on the many conversations she has had with her dad sharing that "When I was a freshman, they had Accelerated Geometry, Accelerated Algebra II, and Accelerated Trig, but there was no distinct difference between the two sets of classes. He's working on equity, so he cut those out. They fixed that" (interview, October 22, 2018).

Participant F also discussed the importance of effective teaching learning practices and although she did not specifically discuss culturally relevant pedagogy her comments suggested this stating that her practicum "class has worked a lot on culturally diverse literature, but I want to find a way to do that in math. It might look a little different, but I want to try and do that" (interview, October 22, 2018). Participant F described an experience she had in Social Studies that made her realize how needed this was based on a diverse group of students' lack of awareness of diverse historical figures.

Throughout the data are examples that suggest that Participant F had consistent access to a high-quality curriculum in mathematics. Experiences related to teaching and learning were described as both effective and ineffective, however because she reported high-levels of mathematics achievement, effective teaching and learning was likely a factor. Participant F did describe experiences that included others having high expectations of her. Participant F's beliefs developed over time through these experiences and filter her current perceptions related to equity. Participant F's perceptions of equity were predominately associated with her gender identity and future oriented teacher identity (Appendix F).

### **Participant G**

**Internally and externally defined dimensions of identity.** Participant G described her various identities as a "contradiction to what you think the pre-made setting is which is a White

middle-class male” (interview, October 22, 2018). Therefore, Participant G identifies as a female, with “long brown hair in the sea of other White girls with long brown hair.” (interview, October 22, 2018). Although she lives in a predominantly Republican state, she identifies as a Democrat. Participant G considers the culture of the Midwestern university town in which she has lived for many years as a part of her identity.

Participant G is the daughter of a mathematics professor, a sister, a girlfriend, and a marching band team member. Participant G has held a future-oriented identity as a teacher stating that “I have always known I wanted to do elementary education, ever since I was in elementary school” (interview, October 8, 2018). Participant G’s interest in education may have been influenced by the many educators in her family; however, to confirm that her interest was beyond this influence, she took the opportunity in high school to work with children.

Participant G does not consider herself to be a great student sharing that “I’m not naturally an A+. I’m naturally a B” (interview, October 8, 2018).

“I think I’m just average at pretty much everything I do. I think I’m a pretty normal human, not especially extraordinary. Just I’m doing what I’m supposed to be doing at all times” (Participant G, October 22, 2018). Participant G would describe herself as a creature of habit who at times is afraid of new things. Participant G considers herself to be dependable, a characteristic she did not identify within the people in her life growing up, other than her mother. Discussing how other people see her made her slightly uncomfortable. “I feel very embarrassed because I’m about to say some very nice things about myself” (interview, October 22, 2018). Those close to her would describe her as a hard worker, resilient, and strong. Her mom describes her as someone who has “this light inside of [her] that if [she] is in the right mood, [she] can bring joy into the world” (interview, October 8, 2018). The notion of “other” as an identity marker

emerged as she discussed how those within her cohort would describe her. Within the cohort, she feels that there are many students that have interests associated with the “sorority side of life” (interview, October 8, 2018). Because this is not aligned to her interests, she has a sense of “other” within the cohort. At the surface, this may convey a sense of exclusion or loneliness however, the way in which she expressed this actually reflected a productive sense of self.

**Beliefs about competence and performance.** Although Participant G has moved through an advanced path in mathematics that culminated with AP statistics in high school, she seems tentative in her beliefs about her competence and performance in mathematics. This, in part, may be due to her family dynamic. Her mother is a mathematics professor and described this as “an amazing blessing and curse” (mathematics autobiography, August 21, 2018). Although they have a very close relationship, mathematics has been a point of stress and frustration. Participant G has vivid memories of completing mathematics homework late at night sharing that “there were nights where I would become so defeated and embarrassed that we would have to work through my crying” (mathematics autobiography, August 21, 2018). Participant G still feels “trepidatious asking her math questions because [she] remember how it felt to be unable to grasp concepts that seemed easy coming out of her mouth” (mathematics autobiography, August 21, 2018). Further complicating this dynamic was Participant G’s feelings of shame related to asking for help in classes that were not considered the most advanced. Additionally, Participant G has an older brother who she identified as a genius and “was absolutely what you would expect the son of a math professor, who is a genius, to be” (interview, October 22, 2018).

Participant G shared that her mother “was doing her best to explain things to me, but sometimes it just wouldn’t click, or she would say I just wasn’t letting it click” (interview,

October 8, 2018). Many describe learning mathematics in way that suggests that it is not due to effort and persistence but rather due to some unknown phenomenon. This is also likely associated with Participant G's belief that she is naturally a B student. Although Participant G alluded to beliefs about natural ability, she also has a sense of self-efficacy and agency as it relates to learning mathematics sharing that "I've found that anything that I put my mind to I can pretty much get. I just have to put enough effort into it" (interview, October 22, 2018)

Comparisons to define her competence and performance extend beyond her family to her classmates. In high school she described her friends as "super smart" (interview, October 22, 2018) and considered herself to be "below them compared, even though [she] was in AP Statistics or AP classes. [She] was still not quite at their level. So, [she] was very humbled by them all the time with what they were doing" (interview, October 22, 2018).

Participant G acknowledges that these beliefs about competence and performance are situated and dynamic based on the participants within the sociocultural context sharing that she feels more confident now that she "is surrounded by people who [she] think[s] are about my level at everything" (interview, October 22, 2018). Participant G went on to reluctantly disclose that she actually "thinks [she] [is] slightly above some of [her] classmates" (interview, October 22, 2018). This confidence is related to test-taking and beliefs about speed and performance, a commonly held misconception in mathematics. Participant G shared that she was able to complete the test in under 10 minutes and believes that "test-taking speed translates a lot in [her] head to how easily they're grasping the concepts" (interview, October 22, 2018).

Participant G's confidence was diminished when she struggled through mathematics content that she believed should not create a challenge for her. Throughout our conversations she discussed her feelings of frustration and embarrassment related to geometry because she believed

she should be “picking it up easily” (interview, October 8, 2018). At times this frustration leads to intense emotion. Participant G described a recent experience that brought her to tears. She was frustrated because it was, “an elementary math class” (interview, October 8, 2018). She shared that she would have felt differently if it was an upper level mathematics course. Participant G also associates these types of experiences with a sense of loneliness describing it as being “stuck inside my brain and [she] cannot get the thoughts going on in here to work out here, then I just don’t want to talk to anyone. I don’t want to see anyone” (interview, October 22, 2018).

Participant G elaborated upon this stating that “instead of a classroom of people working together to solve the same problem, it felt like they were moving forward, driving at 60 miles an hour, and I was stuck at 30 in a school zone. Very much alone” (interview, October 22, 2018). Embedded within this seems to be an extreme performance expectation that she has for herself rooted within her family dynamic. In contrast, Participant G’s confidence increases when she enjoys the content and has been successful with it in the past. She joyfully described the statistics and probability unit as a weight off her shoulders because she was confident that she would “nail the last section of math” (interview, October 22, 2018).

**Beliefs about recognition.** The most influential recognition Participant G can receive is from her mother. She shared that “she is my only connection to math, I would say. It’s more important what she thinks of my abilities than any test score I’ve ever gotten” (interview, October 22, 2018). In addition to the influence of her mother, Participant G also acknowledged the power of recognition by those situated within a role of power or authority. Participant G shared that “[she] [is] a person who thrives on anyone above [her] giving [her] a pat on the head.... any time a teacher does that, [she] will remember forever that they said [she] did a good



job” (interview, October 22, 2018). This type of recognition also influenced her beliefs about competence and performance particularly when a teacher publicly acknowledges her thinking.

Not only is teacher recognition influential so is peer recognition. Participant G believes her peers recognize her as mathematical. However, Participant G’s awareness of the sociocultural dynamics within her cohort mediate her participation. She described herself as the “annoying person who answers all the questions in class” (interview, October 8, 2018). Although other participants discussed mediating their participation as a means to manage other students’ perceptions, Participant G was more concerned about “robbing other people of the chance to reach a conclusion on their own” (interview, October 8, 2018). This perception suggests that an answer is being provided rather than a solution method being shared.

Participant G discussed mathematics course placement as a type of recognition and the impact that being on the advanced path had on her confidence and interest. Participant G expressed that if she had been recognized by being placed on the most advanced path, she would have been successful. This is based on her beliefs about effort and ability. There is tension between these beliefs as Participant G shared that the track you are assigned to in high school is a reflection of who someone is and because of this “could lead to some feelings of maybe disappointment or embarrassment” (interview, October 22, 2018). This perception of effort seems to be related to a deficit in motivation or work ethic that is associated with her core identity as a hard worker. Not being considered a hard worker or not exhibiting enough effort has created feelings of shame for Participant G thus being assigned to a certain track reflects both effort and ability. This is void of an understanding related to the opportunity gap many students experience.

**Interest.** Since Participant G is the daughter of a mathematics professor, mathematics has always been present in her life. However, there was not an expectation by her mother to focus on mathematics. Participant G seems to have a neutral interest in mathematics stating that “despite some painful memories, math, as a subject area has never been my least favorite class” (mathematics autobiography, August 21, 2018). However, this neutrality is not present when discussing her experience with AP Statistics. Participant G shared that “AP Statistics changed my relationship with math. Where before we were distant cousins, familiar but wouldn’t be invited to each other’s weddings, math and I became good friends” (mathematics autobiography, August 21, 2018). This reflects the role of the teacher as the relational conduit between their students and mathematics. Because of the interest of teacher this was the first time Participant G “felt that math had a place in my life and was worth learning” (mathematics autobiography, August 21, 2018). Participant G elaborated on this in our conversations, underscoring the role that her teacher played in the interest and enjoyment in this course. Participant described this as her teacher having an amazing ability to make mathematics meaningful by connecting it to their actual lives. (interview, October 8, 2018).

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant G (Appendix F). The factors of competence and performance, and recognition were most prominent in the data.

**Perceptions of equity through salient identities.** Participant G has a strong sense of empowerment as a female in mathematics. When asked if her identity as a female impacted her mathematical identity she emphatically stated, “absolutely not. It never would’ve occurred to me that women are worse in the STEM fields at all, that they would perform lower, just because of

who my mother was” (interview, October 22, 2018). This question evoked emotion likely because I framed it through the context of the White male identity marker that Participant G had shared previously. As we discussed the notion of gender in mathematics and the transfer of the teacher’s perceptions and beliefs about mathematics to the students. Participant G pondered the influence a female teacher has on both male and female students. She contemplated the notion that female students “have been trained to be more empathetic with their teacher or to feel what their teacher is feeling more than the boys who have not been pushed in that direction” (interview, October 22, 2018). Participant G was cautious in these thoughts because she feared they were a reflection of negative gender norms. We then discussed how this related to a teacher’s mathematical identity and she is aware of the influence her mathematical identity will have on her students. Participant G takes a content specific view of her mathematical identity sharing that her students may be negatively influenced by her beliefs and feelings related to geometry.

**Perceptions of equity through sociocultural experiences.** Participant G would describe the university town she lives in as diverse and accepting. Because of this, it has created a sense of awareness related to issues of equity. Participant G shared that in high school she had friend who identified as a trans woman and their mathematics teacher would frequently use the incorrect pronoun in referring to her. Many students believed this was intentional and because of that Participant G described this as very dark experience because she perceived the teacher was creating a safety issue by not accepting her friend’s gender identity. She observed a friend that was generally upbeat become very quiet and closed off in this mathematics class. Although this perception reflects an awareness of the power of the teacher has to mediate the dynamics within the classroom Participant G also stated the teacher’s primary role is to deliver content.

Participant G shared that “the people who knew this teacher better, would complain about her as a human being, I’d just kind of shrug. She’s doing her job as a math teacher, and that’s all I can ask” (interview, October 22, 2018).

Participant G also has a sense of the complex challenges associated with retaining high-quality experienced teachers within certain school districts. She shared that “in schools in bigger cities that have higher populations of students with more needs tend to get the worst teachers. Not the worst, but the newest, like me” (interview, October 22, 2018). She considers this to be one of the many “intricate moving pieces” (interview, October 22, 2018) that prevent students from receiving an equal opportunity let alone equitable opportunities through education.

Another issue related to equity that Participant G discussed was the unintentional tracking systems that occur within elementary classrooms through ineffective grouping practices. During her practicum experience she has observed that the teacher homogenously groups students all day with little academic progress. She expressed concern that students do not have the opportunity to learn from and with their peers in productive ways. In particular, Participant G has noticed that the students who are perceived to be above level have more independent time and less teacher support. Participant G believes the teacher’s intention are positive but the execution is flawed.

Throughout the data are examples that suggest that Participant G had consistent access to a high-quality curriculum in mathematics. Experiences related to teaching and learning were generally described as effective. Participant G did describe experiences that included others having high expectations of her. Additionally, Participant G has very high expectations for herself. Participant G’s beliefs developed over time through these experiences and filter her current perceptions related to equity. Participant G’s perceptions of equity were predominately

associated with her gender identity, geographic identity marker, and future oriented teacher identity (Appendix F).

### **Participant H**

**Externally and internally defined dimensions of identity.** Participant H identifies as a daughter, older sister, granddaughter, and niece, from a midsized Midwestern city. When asked to further elaborate about the externally defined dimensions of her identity, Participant H responded, “I am an educated Black female. That says a lot” (interview, November 1, 2018). Participant H has “always had a higher standard of education” (interview, October 19, 2018). This was attributed to her family’s focus on education and is the reason she is pursuing a teaching degree. Participant H shared that “[her] grandmother was a special education teacher.... [Her] aunt, was a cosmetology teacher. [Her] dad, he substituted for a while, and then he ended up being a social worker, so, in a sense, he was still kind of teaching people” (interview, November 1, 2018). Participant H is the oldest daughter, and at times her “brother and sisters say [she] gets on their nerves when it comes to education. They say [she] acts like their mom. [She] makes sure [she] pushes them, and makes sure everything’s together” (interview, November 1, 2018). Participant H would describe herself as intelligent, understanding, and compassionate, and others would describe her in this way too. Participant H’s compassion for others drives her “to make sure that everybody is as comfortable as possible” (interview, November 1, 2018).

Recently her co-teacher in her practicum made her feel smart because she recognized the value of the lesson ideas Participant H shared. Participant H described this interaction stating that “I’ve been coming up with a lot of the lesson ideas. She’s like, oh, my god. That’s amazing. We should do more stuff like this” (interview, November 1, 2018). However, it was uncomfortable for her to discuss this. “I really have trouble when people ask me what my strong suits are”

(interview, November 1, 2018). Participant H stated that in mathematics her peers “would probably say that I’m pretty smart just because in class I do know most of the answers” (interview, October 19, 2018); however, she sees herself as “pretty average” (interview, October 19, 2018).

**Beliefs about competence and performance.** Participant H’s confidence in mathematics was shaped by several experiences throughout her education; a primary influence was attending a Montessori school. The student-based curriculum structured learning through uninterrupted, self-directed blocks of time. Participant H had the freedom to explore mathematics at her own pace, and she considered herself to be “a higher speed child” (interview, November 1, 2018). Because she moved at a faster pace, Participant H felt that she benefited from the personalized instruction and extra time with her teacher sharing that “there were a lot of one-on-one lessons with math and I felt that it helped me a lot” (interview, October 19, 2018). However, when performance expectations were more traditional in nature and no longer self-paced, it created challenges for her. Participant H recalled that timed assessments in sixth-grade created stress.

Participant H’s beliefs that learning primarily occurs through individual self-paced experiences prevented her from seeking support from her peers or teacher when she first enrolled in College Algebra and because of this she had to retake this course twice. She shared that the pace was too fast and by the time she realized this she felt that it was too late to ask for help. This belief has endured even though she credits her success when retaking College Algebra to engaging with her peers and teacher for support. Participant H believes she is “capable of understanding [mathematics] eventually” (interview, October 19, 2018), but gets frustrated when it requires multiple attempts, or it takes too long. Participant H stated that “I’ll try and teach it to

myself a few times. If I don't get it, then I'll just give up and that's just how it's been with math" (interview, October 19, 2018).

Throughout her Montessori experience Participant H was in multi-age classrooms where students "move on and everybody goes about their business" (interview, November 1, 2018), and because of this Participant H stated there was not a clearly defined learner hierarchy within the classroom based on perceptions of competence and performance. Participant H shared that "sometimes there were topics where I was high-achieving, but then there were some that I was regular level. So, it wasn't really a hierarchy, just because everybody had their advantages at some point" (interview, November 1, 2018). However, this dynamic changed when she was in eighth grade and placed in a mathematics class with tenth-grade students. It was through this experience that she began to develop beliefs about competence and performance through peer comparisons sharing that "when I achieved in that class, it felt really good because the upperclassmen sometimes didn't understand it" (interview, October 19, 2018).

Participant H's beliefs about competence and performance have shaped her future-oriented teacher identity as she has chosen elementary education rather than secondary education because of her beliefs associated with being able to effectively teach mathematics in middle school or high school. Participant H expressed this belief and decision during our discussions as well as in her mathematics autobiography but cited mathematics anxiety as the reason stating that "[math anxiety] is one of the reasons why I wanted to teach younger grades. I would feel more confident teaching them the things that I understand clearly compared to higher math subjects like Calculus" (mathematics autobiography, August 23, 2018). During our conversations Participant H described feelings of frustration related to mathematics that may be associated with mathematics anxiety. Participant H shared that "you've tried, and you just don't get it. That's one

of my biggest pet peeves with math. You try, and you try, and you just can't make sense of it. It's really frustrating" (interview, November 1, 2018). Participant H stated that this process creates a sense of "failure in some instances" (interview, November 1, 2018) because "math is one of those where it's either you get it, or you don't" (interview, November 1, 2018). This suggests a belief that being able to understand mathematics is due to a natural ability rather than effort. Participant H shared that "it's a really joyous occasion" (interview, November 1, 2018) to get the correct answer regardless of the amount of effort put forth. When approaching a unit of study in mathematics, Participant H feels "happy when [she] starts a unit, and [she] looks at all the topics and [she's] like 'I already understand that. I understand that.' [She] [doesn't] really have to try as hard as [she] would, say in the last unit or something" (interview, November 1, 2018).

**Beliefs about recognition.** Because Participant H attended a Montessori school, with multi-age classrooms, where students learned at their own pace to achieve mastery, formal recognition was not a dominant factor shaping her mathematical identity. Participant H shared that "it never really bothered [her] if a teacher acknowledged [her] or not. [She] wasn't really looking for recognition" (interview, November 1, 2018). Participant H did identify the informal recognition she received from peers when they would ask for help and the influence that had on her confidence.

In sixth grade, Participant H described an experience that identified her as student that was struggling to master multiplication and because of this had to stay inside and work on mathematics during recess. This negative recognition caused her "to worry about being singled out" (interview, November 1, 2018), and once she was out of that group, she expressed a sense of relief. Unfortunately, the practice of timed assessments and the label that resulted had an



enduring impact on Participant H's beliefs about competence and performance as she stated that she is "still working on automaticity" (interview, November 1, 2018).

It was not until Participant H was in high school that recognition seemed to have a stronger influence on her beliefs. This may be in part due to maturation, but it also may be attributed to the sociocultural dynamics within a traditional school structure, and the influence of her mathematics teacher. She had a positive experience with a teacher who she described as joyful. Because of her connection to this teacher, his recognition was meaningful to her. Recognition from the teacher has continued to be important to Participant H. Participant H shared that "in class I get called on a lot. It's not necessarily a huge recognition, but just her calling on me and getting the answer right is pretty rewarding for me" (interview, November 1, 2018). This recognition influences her beliefs about competence and performance stating that "when she does give me that recognition it helps me understand that I'm on the right track" (interview, November 1, 2018). Additionally, Participant H shared that she answers questions in her mathematics classroom "to keep the class moving" (interview, November 1, 2018), and because of this, others may see her as "an amazing math person" (interview, November 1, 2018).

**Interest.** Participant H's interest in mathematics is related to her beliefs about mathematics. "I do enjoy math compared to other subjects because with math there is one to two specific answers for each question" (mathematics autobiography, August 23, 2018). Participant H views mathematics as computation, describing mathematics as "just making sense of numbers, basically. Having different equations, where you have to make sense of them to come up with the logical answer" (interview, November 1, 2018). When asked to describe the purpose of mathematics, Participant H was not able to "think of anything huge" (interview, November 1,

2018), but did mention that mathematics is useful in construction, architecture, and time management which she categorized as “simple stuff” (interview, November 1, 2018).

Although Participant H enjoys mathematics, she prefers literacy at times. This interest in literacy is attributed to her grandmother who she considered a role model. She shared that “she was huge on reading, she put books in front of me and my little siblings when we were like two, three years old. I was in third grade reading on like a seventh-grade level” (interview, November 1, 2018). Participant H did not identify a specific mathematics role model; however, she did share a vivid memory of her eighth-grade Algebra teacher. His interest in mathematics created a positive environment where students were motivated to excel. Participant H described this experience as her best mathematics experiences because the teacher “took the time out and really made it an enjoyable environment to be in.... You could tell that he loved his job and really wanted to be there with us (interview, October 19, 2018). The perceived interest of the teacher and the investment the teacher made in the student’s success influenced Participant H’s interest in algebra. During the following school year, Participant H was enrolled in Geometry and the absence of an invested teacher influenced her interest in geometry as she views geometry as “a few topics and then that’s basically it” (interview, October 19, 2019), whereas with algebra “there is still so much to learn about it” (interview, October 19, 2019).

As Participant H continued through high school, her interest decreased as the mathematics became more challenging sharing that “the older I got, and the more complicated the math got. The more I got discouraged and stopped really trying to learn since it was too hard” (mathematics autobiography, August 23, 2018).

Through the analysis of the narrative description, a data map was created to represent the relationship between competence and performance, recognition, and interest for Participant H

(Appendix F). The factor of competence and performance was most prominent in the data for Participant H.

**Perceptions of equity through salient identities.** Participant H identifies as an educated Black female. She described her Montessori school as being diverse and a source of motivation for her to excel academically. Her elementary experience included “an equal split between African Americans and White [students]” (interview, November 1, 2018). However, her social group was primarily African American, and she felt compelled to let others know that “I’m just as smart as you guys, and I can keep up” (interview, November 1, 2018). Once she reached middle school, many of the White students moved to private schools and she felt like she had lost her motivation and then “started slacking off and not really being extraordinary” (interview, November 1, 2018). She attributed this decrease in motivation to not being able to see the difference between herself and her African American peers. Additionally, Participant H believes the change in diversity was due to the fact that the White students had the financial means therefore the opportunity to attend private schools. Furthermore, she felt the negative reputation of the school district, an urban district that is provisionally accredited by the state, diminished the reputation of her high school despite that fact it had earned numerous awards and was considered number one in the city.

Participant H’s current school context is not diverse; however, she appreciates that her cohort is predominantly female sharing that “being in an all-female class is pretty good for [her] just because [she] feel[s] more open to talk to them about math” (interview, November 1, 2018). Participant H is aware of the gender stereotypes in mathematics and the impact of this on her beliefs about competence and performance. She stated that the, “stigma that men are better in math...kind of hangs over my head” (interview, October 19, 2018). Participant H attributed the

various engagement levels in mathematics classrooms to gender differences stating that “males are more competitive than females. They’d be the one answering all the questions, and really engaged in the conversation in class, where we’re kind of passive. We sit back, and if the teacher calls on us, then okay” (interview, November 1, 2018).

Although Participant H appreciates the benefits of a predominantly female cohort, she also discussed the differences between herself and her peers based on her perceptions related to socioeconomic privilege. Participant H shared that “I am different than a lot of my peers. It’s harder at some points to relate to them. A lot of them have been out of the country and have had two or three cars. Their parents pay for college” (interview, November 1, 2018). Related to this is the perception that most of the students in the cohort belong to a sorority. Participant H shared that during her first year in the teacher preparation program it was a more distinct group. According to Participant H, these students tended to come to class together and sit together, but now the students are bonding through the collaborative nature of their practicum experience. Generally, Participant H described her cohort as a supportive community.

Participant H plans to teach in a school with a professional development focus that is associated with the university and feels that the multiple dimensions of her identity will be beneficial to her students.

**Perceptions of equity through sociocultural experiences** Participant H’s notion of equity in mathematics includes “giving everybody an equal opportunity” (interview, November 1, 2018). Like many, Participant H is grappling with both the relationship and differences between equity and equality.

Participant H’s beliefs about student choice, based on her Montessori experience, provided a foundation for understanding agency, an essential element of equity. Participant H

identified choice as the primary reason she preferred her Montessori experience over her traditional experience. Participant H compared this to her traditional school experience, stating that she “felt like it was on a schedule. We had to do exactly what they said and turn it in exactly when they said” (interview, November 1, 2018). Participant H’s beliefs about student choice were reflected in her observation of her practicum experience: “The students do have some say in what goes on in the classroom, I’ve noticed. There is a lot of different stations. The students do learn through different ways throughout the day” (interview, November 1, 2018). In addition, having a choice was an important element of Participant H’s Montessori experience, and so was the opportunity to learn at an individual pace. Participant H described an experience during her practicum in which the same group of students continually lost recess time because they could not complete the mathematics warm-up in the allotted time. Because Participant H had a similar experience of losing recess for not being able to complete the timed assessments, she was concerned about the negative impact of this on the students.

Throughout the data are examples that suggest that Participant H had consistent access to a high-quality curriculum in mathematics. Experiences related to teaching and learning were described as both effective and ineffective. Participant H did describe experiences that included others having high expectations of her although based on her Montessori experience she also set high expectations for herself. Participant H’s beliefs developed over time through these experiences and filter her current perceptions related to equity. Participant H’s perceptions of equity were predominately associated with her racial identity and gender identity (Appendix F).

### **Conclusion**

“Stories are data with a soul” (Brown, 2010), creating both a window and mirror for the researcher and participants in this study as we jointly explored the complex topics of

mathematical identity and equity (Drake et al., 2001). The unique life experiences and the multiple identities of each participant have shaped their mathematical identities and their perceptions about equity. The intention of this study was to provide a deeper understanding of these complex topics through a narrative approach. Participants shared their mathematics autobiographies and engaged in conversations retelling and explaining the moments in their lives that were significant in shaping who they are, who they want to become, and how they perceive issues related to equity in mathematics. Through the analysis of the data, the categories of beliefs about competence and performance, beliefs about recognition, interest, perceptions of equity through salient identities, and perceptions through sociocultural experiences were identified. These categories then created the structure for the narrative descriptions for each participant. Within these categories, themes were identified from each of the narratives and then the prominent themes from across the categories were determined to provide a holistic understanding of mathematical identity and perceptions of equity. The holistic themes are presented in Chapter 5 as the case results.

## Chapter 5: Case Results

### Themes

The case results are the themes for this study that represent the recurring patterns that cut across the participant results (Merriam & Tisdell, 2016). According to Maxwell (2013), developing themes are necessary for building understanding. In this study, the themes were identified through a holistic analysis of the narrative and interpretative descriptions across each of the categories and are elaborated upon in this section as a means to answer the research questions (Table 1).

Category	Theme
Competence and Performance	<ul style="list-style-type: none"> <li>• Natural Ability</li> <li>• Peer Comparisons</li> <li>• Teacher Interest and Support</li> </ul>
Recognition	<ul style="list-style-type: none"> <li>• Teacher Recognition</li> <li>• Peer Recognition</li> <li>• Recognition through Assessment Practices</li> <li>• Recognition through Tracking Practices</li> </ul>
Interest	<ul style="list-style-type: none"> <li>• Beliefs about Mathematics</li> <li>• Parental/Familial influence</li> <li>• Teacher Influence</li> <li>• Future Oriented Identities</li> </ul>
Salient Identities	<ul style="list-style-type: none"> <li>• Gender</li> </ul>
Sociocultural Experiences	<ul style="list-style-type: none"> <li>• High-Quality Curriculum – Tracking Practices</li> <li>• Effective Teaching and Learning – Differentiation and Grouping Practices</li> <li>• High Expectations – Teacher Beliefs</li> </ul>

Table 1 Case Categories and Themes

## **Development of Beliefs about Mathematics Competence and Performance and the Influence on Mathematical Identity**

**Natural ability.** Participants' beliefs about mathematics competence and performance are grounded in the notion of natural ability. The participants generally believe that you are naturally good at mathematics or you are not. However, they also believe that competence and performance can be developed through effort. The idea that mathematics “just clicks” for some was a common sentiment. Beliefs about competence and performance are influenced by beliefs about mathematics and the alignment to their core sense of self. Many participants viewed mathematics as linear, organized, and black and white, and also described themselves in this way, thus a natural fit.

**Peer comparisons.** The data strongly suggest that participants' beliefs about competence and performance are shaped through peer comparisons. This notion of how I see myself in relation to how I see others was not strongly articulated in the mathematical identity literature review; however, it was pervasive in the data. These perceptions developed through differentiated instruction, grouping structures, tracking practices, assessments, and likely implicit bias.

**Teacher interest and support.** Beliefs about competence and performance were positively shaped when a teacher demonstrated interest in the participants' success. This was particularly salient during times of struggle with challenging mathematics content. This type of recognition sent a message that the teacher believed in their competence and performance and was therefore willing to invest extra time to support their efforts. However, the opposite was also true. The perception that the teacher did not care or was not willing to invest in their success challenged their confidence and at times diminished their interest in the subject or course.



## **Development of Beliefs About Mathematics Recognition and the Influence on Mathematical Identity**

**Teacher recognition.** Beliefs about recognition, how others perceive the participant, were shaped by people and practices within the sociocultural context. The data in this study provided insights to the explicit and implicit messages from people, structures, and practices that shaped the participants' mathematical identity. As the literature suggests, people have a strong influence on recognition (Cribbs et al., 2015). Recognition from those considered "role models" was particularly influential, thus influencing beliefs about competence and performance as well as interest. Teacher recognition was influential in shaping the mathematical identities of the participants. The participants shared vivid memories of the moments when a teacher acknowledged their mathematical thinking by sharing their solution methods, assigning competence, or suggesting potential. This type of recognition was generally described as influential because it came from someone in a position of power.

**Peer recognition.** Furthermore, participants in this study identified being asked for help by peers as a form of recognition. Although, it is interesting to note that many of the participants also described how they managed peer recognition by tempering their competence and performance in mathematics classrooms so as to not seem "overconfident," "annoying," or to be labeled a "know-it-all." This was especially noted within their current context that is predominantly female.

Peer relationships within the mathematics classroom were also important, especially during high school. The importance of peer relationships was so strong that at times this determined course selections; for some this meant an increase in motivation and effort to move into the advanced tracks, and for others this meant moving out of the advanced tracks. One

participant even declined the opportunity to begin advanced mathematics coursework to remain in the same class with her friends. Additionally, because many of the participants were in the advanced tracks in mathematics, they were placed in classes with older peers. For some participants, this was uncomfortable but also increased beliefs about competence and performance.

**Recognition through assessment practices.** Assessment practices are a form of recognition and were a focus throughout the participants' stories. This type of recognition shaped the way participants perceived teachers and peers viewed participants within the sociocultural context. Most of the earliest memories shared by the participants began with a clear description of the timed assessments they took in third or fourth grade. For several participants, these were stories of struggle, failure, frustration, and embarrassment that influenced both confidence and interest. For some, this was a defining moment, heavily shaping their mathematical identity, whereas others were more resistant to the negative influence on competence, performance, and interest. For the participants who experienced positive recognition through timed assessments, this triumph solidified their status within the mathematics classroom and reinforced their sense of confidence.

**Recognition through tracking practices.** Additionally, recognition through placement tests for gifted services or advanced tracks positively influenced interest and confidence; all but one of the participants in this study were recognized as advanced mathematics students in middle school or high school. The participant who was not in the advanced track for mathematics was in the advanced track for literacy, thus experiencing a similar influence for literacy in interest and confidence.

## **Development of Interest in Mathematics and the Influence on Mathematical Identity**

**Beliefs about mathematics.** Like beliefs about competence and performance, there is a sense that there is a natural preference for mathematics for some and not for others. This may be due in part to their beliefs about mathematics and the alignment to the participants' core sense of self. For many of the participants, this natural preference was described through a dichotomy between an interest in mathematics and an interest in literacy. For those who stated a strong preference in mathematics, they described mathematics as a way to expand horizons and connect with people. For the participant who strongly preferred literacy, mathematics was compared to a workout at the gym, necessary but not enjoyable.

**Parental/familial influence.** Mathematics role models for most of the participants were family members. Four of the participants identified a parent who is an educator or a medical professional with a mathematics background. One of the participant's sister is an educator with a mathematics minor. All five of these participants recalled several experiences or feelings associated with these family members that were significant in influencing their interest in mathematics. Of the three participants who did not identify a mathematics role model, two of them identified literacy role models in their family who had a similar influence on their interest in literacy.

**Teacher influence.** Joy was a factor that influenced interest in mathematics, particularly the joy they felt from the teacher. The participants' perception of the interest of the teacher in mathematics and teaching and learning in general was a pervasive theme throughout the data. Participants described those teachers and experiences as joyful. A joyful environment not only increased interest it also influenced confidence in mathematics. Unfortunately, the opposite was true too. All of the participants described experiences where the interest of the teacher was

perceived as negative. For some participants, this decreased interest was temporary but left an enduring belief about the content being taught. For others, this lack of interest by the teacher negatively influenced their beliefs about competence and performance. Relationships within the mathematics classroom influenced interest. Many participants described positive relationships with their teachers and these positive relationships increased interest. When participants felt disconnected from their teachers, interest tended to decrease.

**Future-oriented identity.** The future-oriented identities of the participants played a role in their interest in mathematics throughout their experiences, thus influencing their mathematical identity. The research cited in the literature review suggests that when students experience traditional instruction and that conflicts with their core sense of self, they reject their future-oriented mathematical identity (Boaler & Greeno, 2000). In this study, most of the participants described experiences that were predominantly traditional, meaning that the teacher modeled a problem and then the students practiced solving the problem. This approach likely influenced the participants beliefs about mathematics as being linear, definite, and objective, all characteristics they associated positively with their core sense of self and their future-oriented identities. Many of the participants in the study had identified as a future educator from the time they were very young; however, there were a few participants that made that decision later in life. For those participants, they described an increased interest in mathematics once establishing their teacher identity. The increased interest was attributed to the importance of mathematics and their desire to be an effective teacher. This finding suggests the influence of relevance and purpose on interest related to personal identities.

The previous sections answered the first three subquestions that are aligned to the model of mathematics identity, adapted (Cribbs et al., 2015). However, woven throughout the findings

for competence, performance, recognition, and interest are issues related to equity. Because equity and mathematical identity are critically linked, it was an important focus. Questions asked during the semistructured interviews specifically aimed at uncovering and understanding the participants' equity perceptions. Questions probed on topics related to equity that emerged from the first unstructured interview and the mathematics autobiography. During these conversations, there was a careful, thoughtful tone, and at times, participants seemed almost apologetic with their responses. All of the participants expressed a genuine interest in understanding and honoring the whole child in their future classrooms and acknowledged the power of education to create equitable opportunities. For the fourth subquestion, two categories were identified: perceptions of equity through salient identities, and perceptions of equity through sociocultural experiences. The themes within these two categories are discussed in the following sections.

### **Development of Perceptions of Equity and the Influence on Mathematical Identity**

**Salient identities: gender.** The participants' perceptions of equity are shaped by their personal identities and experiences. These personal identities reflect both externally and internally defined dimensions of identity developed over time through their individual life histories. The Model of Multiple Dimensions of Identity (Jones & McEwen, 2000) provided the conceptual model in which to frame the understanding of the identities shared by the participants. As suggested in this model, the externally defined dimensions of identity that were most salient to the participants were named by the participants during the interviews. All participants identified as female, suggesting the saliency of this externally defined dimension in the context of mathematics. Issues and perceptions related to gender were topics that were discussed by all participants during the interviews, suggesting the influence of these gender perceptions on their mathematical identity. Additionally, participants were asked to describe

their core sense of self. Jones and McEwen (2000) suggest the core identity as “somewhat protected from view” (p. 408), and at times participants seemed uncomfortable discussing this. There was a sense of embarrassment when describing personal characteristics. This may be in part due to a lack of trust that is needed to be truly vulnerable in this type of conversation and developing that type of trust would have required more time. It may also be due to gender norms. Furthermore, participants acknowledged that the nature and closeness of a relationship, such as a family member, determined how fully others recognized the personal characteristic and attributes of their core identity. Generally, participants were more comfortable describing the positive characteristics that others would name about them and were humble related to their own perceptions of self.

**Sociocultural experiences: access to a high-quality curriculum through tracking practices.** All of the participants had access to advanced coursework in middle school and high school in either mathematics or literacy therefore this emerged as a theme within the data. Participants commented about the lack of diversity within the advanced tracks, the gender distribution of the students, and the opportunities the advanced tracks provided them. The perception of status related to advanced tracks was discussed in various ways by the participants. Another widely held perception is that tracking systems prevent access to a high-quality curriculum for students not labeled mathematically advanced or gifted. However, one participant described the sense of being stuck in an advanced track unable to move out of it as needed. Another participant described a perception that the advanced track she was in was in name only, and in fact the “regular” class was more rigorous and progressed at a faster pace. Although being recognized through placement in advanced mathematics tracks and the positive influence that may have had on most of the participants’ beliefs about competence and performance, overall,

the participants perceived tracking as an inequitable practice in mathematics because the potential to negatively impact their future students far outweighed and potential benefits.

**Sociocultural experiences: access to effective teaching and learning through differentiation and grouping practices.** Access to a high-quality curriculum does not necessarily ensure effective teaching and learning practices in mathematics. Because all of the participants described experiences that created inequities related to teaching and learning, this was identified as a theme. In particular, the participants discussed the grouping practices related to differentiation they have observed in their practicum experiences. Many of the participants expressed concern about the impact that these practices will have on the students. The participants acknowledged the influence a teacher has on their students through effective teaching and learning practices, and all of the participants have a strong desire to facilitate mathematics instruction in a way that positively impacts their students. Within these conversations were various associations with MKT (Ball et al., 2008). Some participants discussed mathematics content knowledge, some discussed pedagogical content knowledge, and others alluded to knowledge of the learner, but all of these perceptions were anchored in their previous experiences as a learner and is a reflection of their mathematical identity.

**Sociocultural experiences: high expectations through teacher beliefs.** Expectations are the explicit and implicit messages that people receive from others associated with who they are or who are they supposed to become. Expectations have the potential to empower or oppress people through mathematics. Throughout the data, these expectations were communicated through beliefs statements about past teachers, current teachers, practicum teachers, and even themselves as future teachers. Based on their belief systems, the participants described a commitment to having the same high expectations for all students by treating people the same.

As to be expected, participants have varying degrees of understanding related to equality and equity and the notions of same and fair. In addition, the participants described certain expectations for females in mathematics related to gender stereotypes, and although they resisted them, they acknowledged the power of these beliefs. Further, many participants described perceptions related to family dynamics and socioeconomics and racial diversity that were loaded with stereotypes. Participants seemed to be grappling with these complex topics and the tensions associated with their current and future-oriented identities and equity.

### **Conclusion**

People make sense of the world based on their various filters and lenses that are influenced by their identities and experiences, and in this study the participants' mathematical identities and perceptions of equity reflected this. To answer the research questions, the in-depth, rich descriptions were analyzed, and themes were identified across each of the categories. These themes represent a holistic understanding of the case and provide insights related to mathematical identity and equity in mathematics.



## **Chapter 6: Discussion**

### **Introduction**

Becoming mathematical is a complex process; it is a collection of moments influenced by the multiple identities of an individual, their experiences, and the people within the sociocultural context. For many, this process is full of turning points that shape who they are, who they are not, and who they intend to become. As expected with a descriptive and interpretive case study, the results of this study challenged prior assumptions and developed new and deeper understanding. The results of this study reflect a holistic view of the case – the mathematical identity of elementary preservice teachers.

The primary research question for this study was: How are the mathematical identities of preservice teachers shaped? As suggested in the literature and reflected in the data from this study, mathematical identity is a complex notion. Mathematical identity is shaped through the sociocultural context. Affective factors develop through experiences and emerge in the forefront of the stories people share about who they are. Beliefs related to competence, performance, and recognition as well as interest are critical factors. There is a relationship between these factors that is unique for each individual, thus shaping mathematical identity in unique ways. However, consistent between all of the categories was the influence of the teacher. The stories the participants shared that included a teacher were vivid, emotional, and generally described as an influence on their beliefs, interests, and perceptions. The teacher was perceived by the participants to have power and status within the sociocultural context.

Status is situated within the intersection of mathematical identity and equity. Within the sociocultural context, status is also assigned to people, groups, identities, courses tracks, and content; this status generates power within and among the critical factors. Within this finding is

the tension between power and equity that contributes to the development of perceptions and the shaping of a mathematical identity. Reflected throughout the data are examples of structures and practices that both positively and negatively influenced the mathematical identity of the participants. These examples are riddled with issues of power and inequity thus developing the participants perceptions of equity in mathematics.

Finally, it is interesting to note that the mathematical identities of six of the eight participants would be considered robust. Meaning that they have productive beliefs about their competence and performance, believe others generally recognize them as mathematical, and also have an interest in mathematics. This is contrary to a general perception about elementary teachers as well as the findings of a significant body of research within this domain (Grootenboer & Zevenbergen, 2008; Gujarati, 2013; Jong, 2016; Latterell & Wilson, 2017; Ma & Singer-Gabella, 2012).

### **Discussion**

The results of this study expand upon the results of Cribbs et al. (2015) as the factors of competence and performance, recognition, and interest were identified as the categories that were identified from the data related to mathematical identity. Additionally, much of what was revealed in the results of this study was reflected in the literature review. However, there were new topics of interest that emerged, thus necessitating a need to return to the literature. The following sections expand the notions of competence and performance, recognition, interest, and equity, anchored in the research. In particular, peer comparisons and grouping practices as a means to develop beliefs about competence and performance were further examined. Timed assessment practices were explored related to recognition. A focus on parental and teacher

influences has been included to deepen understanding about interest. Finally, a discussion about gender in mathematics and equity grounded the results of this study.

**Competence and performance: peer comparisons.** Although Cribbs et al. (2015) found that competence and performance are filtered through recognition and interest, thus having an indirect effect on a person's mathematical identity, the data in this study suggest that beliefs about competence and performance were pronounced, indicating a more direct effect. Aguirre et al. (2013) state that a mathematical identity is "how students see themselves and how they are seen by others" (p. 13). What is unstated but implied is an important third prominent dynamic, which is how students see others in relation to themselves. Pervasive throughout the data were peer comparisons associated with beliefs about competence and performance. Bandura (1993) contends that people determine ability by "[assessing] their capabilities in relation to the attainment of others. The people with whom individuals compare themselves influence how they judge their ability" (p. 121). This is what Bandura (1977) referred to as "vicarious experience," which is identified as one of the four primary sources that influence self-efficacy beliefs. Butz and Usher (2015) examined the salient sources of teens' self-efficacy beliefs and found that peer comparisons were a primary source of influence and have the potential to increase and decrease confidence. Additionally, these types of comparisons have the potential to be loaded with both conscious and unconscious beliefs about who other people are; therefore, shaping unproductive beliefs and perceptions.

**Competence and performance: grouping practices.** Another practice the participants related to peer comparisons was that of grouping practices associated with differentiation instruction. In this study, this was discussed primarily in the context of their practicum experiences and their intentions for the future. Participants' concerns were focused on the

potential negative influence on students' competence and performance when recognized, or labeled, a certain type of learner based on grouping practices during differentiated instruction. Bannister (2016) cautions against differentiated instruction that creates within-classroom tracking practices based on perceived ability and readiness labels. According to Banks (2013), homogenous grouping "invites reproduction of status ordering from the larger society into the classroom that move us away from, not toward our democratic values and empowerment of students" (as cited in Bannister, 2016, p. 345). Park and Datnow (2017) posited that ability grouping has increased due to data-driven practices associated with accountability. Consistent with the findings in this study, Park and Datnow (2017) found that "teachers often attached values of equity to [differentiated instruction] practices while acknowledging that there was a gap between the expressed ideal and what was actually practiced" (p. 300). This finding was reflected in participants' observations as many of expressed developing effective practices to meet the needs of each student as a future challenge.

**Recognition: timed assessments.** As mentioned previously, Cribbs et al. (2015) suggest that recognition is paramount for developing productive mathematical identities. Recognition is described as "how students perceive others to view them in relation to mathematics" (Cribbs et al., 2015, p. 1052). The data in this study suggest that these perceptions and beliefs develop in many ways. One significant influence was that of timed fluency assessment in the elementary grades. These assessment experiences shaped how participants believed others perceived them, but most importantly how they viewed themselves. According to Boaler (2014), "students across the United States come to believe that fast students are those who have the most potential, meaning that many slower but deep thinkers turn away from math" (p. 471). Not only does this create an unproductive belief about who people are mathematically, it also falsely perpetuates the

notion that faster is smarter, and that mathematics is about recall rather than problem solving and reasoning (Seeley, 2015). Many of the participants' beliefs reflected this unproductive belief that being good at mathematics means that you are fast at mathematics. Furthermore, they described these assessment practices as frustrating and diminishing.

**Interest: parental influence.** *Interest* is defined as the “desire or curiosity to learn mathematics” (Cribbs et al., 2015, p. 1052). Cultivating a desire or curiosity in mathematics is inherent in the first key recommendation in *Catalyzing Change* (NCTM, 2018), which states that “each and every student should learn the Essential Concepts in order to expand professional opportunities, understand and critique the world, and experience the joy, wonder, and beauty of mathematics” (p. 7). Although learning essential concepts is important for developing a relationship with mathematics, people cultivate joy, wonder, and beauty in mathematics through human connection and the relationships within the sociocultural context. Within this study significant relationships influenced participants' interest in mathematics. In particular, mathematics role models were instrumental in shaping interest.

The role models in this study were primarily parents who had a particular interest in mathematics. The research on parental influences is primarily focused on mathematics achievement and gender stereotypes rather than the influence on interest in mathematics. However, in a study conducted by Lazarides and Ittel (2013) the researchers found that a parent's interest in mathematics significantly predicted the interest of females. This finding was not true for males, which is important to consider in the context of this study as all of the participants identified as female. In another study, Frenzel, Goetz, Pekrun, and Watt (2010) concluded:

As expected, family and classroom values as well as teacher enthusiasm positively related to students' levels of interest during grades 5–9. Above and beyond within-

student effects on interest, exposure to high parental and classroom values over this entire developmental period was associated with overall higher interest levels across students.

This supports the notion that parents, and teachers act as role models and transmit their expressed values to the adolescents. (p. 530)

As suggested in these findings, both parents and teachers shaped the interest of the participants, another important theme that emerged in this study.

**Interest: teacher influence.** Grootenboer and Zevenbergen (2008) identified the teacher as the key dimension within the learning milieu, stating that “the mathematics teacher is a relational conduit between the student and mathematics” (p. 247). The researchers theorized that effective teachers introduce mathematics to students “in a way one would introduce a friend. The students must know why the teacher values the subject” (Grootenboer & Zevenbergen, 2008, p. 246). The researchers suggest that this occurs through the personal and pedagogical relationships the teacher develops with the students. The role of the teacher is temporal, but what endures is the interest of the student and the influence on their mathematical identity (Grootenboer & Zevenbergen, 2008). In this study, this relationship emerged throughout the data and was clearly articulated in the Participant G’s mathematics autobiography.

AP Statistics changed my relationship with math. Where before we were distant cousins, familiar but wouldn’t be invited to each other’s weddings, math and I became good friends. For the first time I felt that math had a place in my life and was worth learning. I believe I had a particularly good stats teacher. (mathematics autobiography, August 21, 2018)

Moreover, in a study conducted by Latterell and Wilson (2016), the researchers analyzed the mathematics autobiographies of secondary mathematics preservice teachers in an effort to

understand the participants' interest in mathematics. The results identified the teacher as a primary factor, specifically the enthusiasm of that teacher for mathematics (Latterell & Wilson, 2016). Again, this aligns to the results of this study as the participants recalled vividly how the teachers in their stories shaped their beliefs and interests.

Not only was the interest of the teacher in mathematics important, the interest of the teacher in the student was also significant to the participants in this study, further supporting the study conducted by Grootenboer and Zevenbergen (2008). Throughout the data in this study are examples of caring teachers that positively influenced both the interest of the participants and their beliefs about competence and performance. This finding was also articulated in a study conducted by McCulloch, Marshall, DeCuir-Gunby, and Caldwell (2013) focused on the mathematical identity of K–2 teachers. The researchers found that “a caring teacher who took an interest in them” (McCulloch et al., 2013, p. 387) influenced a change in perceptions from positive to negative. This was particularly significant for the participants in this study during times of struggle. The absence of a caring, interested teacher was also present in the stories of the participants in this study and was the reason many of them cited for decreased interest and confidence.

Additionally, the participants in the study conducted by McCulloch et al. (2013) described a positive and fun atmosphere created by the teacher, a reflection of the teacher's interest, as an “impetus for a personal transition” (McCulloch et al., 2013, p. 387). The notion of fun was salient for several participants in this study. It was described as gift of and from the teacher to the participants and a means for creating a sense of joy in mathematics. This is further triangulated in the findings from Grootenboer and Zevenbergen (2008) and McCulloch et al. (2013).

**Perceptions of equity: gender.** Mathematics has a long history of privileging a few and excluding many because of bias and stereotypes (Gutiérrez, 2013). This is the intersection between mathematical identity, the Model of Multiple Dimensions of Identity (Jones & McEwen, 2000) and equity—a symbiotic relationship and a reflection of the theory, purpose, and overarching goals of this study. A broad examination would include issues related to all externally defined dimensions of identity; however, that is beyond the scope of this discussion. Because all of the participants in this study identified as female, and gender norms, stereotypes, and biases have plagued equity in mathematics, that is the primary focus of this discussion. Gender was a prominent theme throughout the data. Myths related to natural cognitive abilities in mathematics based on gender have been thoroughly debunked and dispelled through research (Cimpian et al. (2016); Radovic et al., 2017; Salikutluk & Heyne, 2017; Wang & Degol, 2016). The participants in the study have been empowered to succeed in mathematics through various means such as privilege, parental influence and support, and education; however, beliefs about gender are deeply rooted in society. The participants in this study strongly rebuked the notion that “girls are not good at math.” However, they also shared stories about tempering their mathematics engagement to align to gender norms. Gender beliefs within the sociocultural context reflect a dynamic state of confirmation and refutation. This dynamic was also present in the findings of Radovic et al., (2017). The researchers found that despite having positive mathematical identities, gender mediated the girls’ relationships with mathematics through their peer groups as they exercised genderized social roles to determine where they belonged (Radovic et al., 2017). The researchers described a tension among the participants as they negotiated becoming and belonging and the influence of gender roles, norms, and stereotypes (Radovic et al., 2017). Many of the participants in this study expressed a tension with belonging within their



current predominantly female context, whereas others felt a sense of community and support because of the gender dynamics. These findings further underscore the need for new and enlightening transformational inquiries that provide evidence and insights to the underrepresentation of women in mathematics and STEM-related fields.

### **Implications**

The implications for this study are of particular interest for those who support teacher growth and development, particularly teacher preparation programs, school districts, and professional learning organizations. “Professionalism” is one of six guiding principles in *Principles to Actions* (NCTM, 2014) that make up the “strongly recommended, research-informed actions for all teachers, coaches, and specialists in mathematics; all school and district administrators; and all educational leaders and policy makers” (NCTM, 2014, p. 4). According to the authors, “in an excellent mathematics program, educators hold themselves and their colleagues accountable for the mathematical success of every student and for personal and collective professional growth toward effective teaching and learning of mathematics” (p. 99). The aim of this principle is to create a “culture of professional collaboration” (NCTM, 2014, p. 107), and this requires those who lead transformational efforts to take a holistic stance, recognizing the culture is made up of individuals, and successful efforts must engage the hearts and minds of these individuals.

We must engage educators in a narrative process to shift perceptions about mathematics and equity in productive ways. Feedback from one of the participants in this study to the instructor indicated how beneficial participation in this study was because it provided a process for self-reflection that allowed her to see herself more clearly. This clarity is essential for developing productive relationships with oneself, students, colleagues, and mathematics.

According to Brown (2015), “you either walk inside your story and own your truth, or live outside of your story, hustling for your worthiness” (p. 45). This is true for our mathematical identity and our perceptions related to equity; as it is through our stories that we connect more deeply with ourselves thus creating the conditions for inclusivity and true belonging within our mathematics classrooms.

Furthermore, through the frame of the Access, Equity, and Empowerment Principle (NCTM 2014; NCSM & TODOS, 2016), pragmatic implications for practice for preservice and inservice teachers must include a focus on the influence of equitable access to a high-quality curriculum, effective teaching and learning, and high expectations as reflected in the findings of this study. Collectively, these practices shape the beliefs about competence and performance, interest, and recognition thus shaping the mathematical identity of the individual. These practices create barriers or open doors, leaving enduring perceptions about who and how people are empowered to participate and contribute in mathematics. Within the MKT framework (Ball et. al, 2008) is the construct of Knowledge of Content and Students (KCS) representing the importance of understanding and honoring the multiple identities of each student in the mathematics classroom. Both Ladson-Billings (1995, 2014) and Paris (2012) expanded the notion of KCS to include critical consciousness that attends to the conceptions of self and others and social relationships. *Catalyzing Change* (NCTM, 2018) recommends that schools “discontinue the practice of tracking teachers as well as the practice of tracking students into qualitatively different or dead-end course pathways” (p. 15).

Effective teaching and learning is the spark within the sociocultural context; it has the potential to empower or oppress those within it. This is a place that the individual teacher has the greatest opportunity to make the biggest impact. Based on the findings of this study, special

attention must be paid to how students are positioned within the classroom through assessments and differentiated instruction. A source to guide this focus are the equitable pedagogic actions in *Catalyzing Change* (2018) that are aligned to the eight mathematics teaching practices (NCTM, 2014) described in Chapter 2. “The eight Mathematics Teaching Practices...provide a framework for making connections between these high-leverage practices and the development of identity, agency, and competence” (NCTM, 2018, p. 29). This framework should be the foundation of the work for those who support teacher professional learning and teacher development in mathematics. Finally, the influence of high-expectations for each and every student cannot be overstated in shaping mathematical identity and empowering people in mathematics. It is here that we must examine our beliefs and perceptions about equity. We must have the courage to have hard, uncomfortable conversations that challenge our assumptions and unearth our biases. According to Howard (2018),

It is human nature to disengage from conversations that make us uncomfortable. Create the necessary circumstances to reduce the ability for participants to disengage. Be open to calibrating the experiences to help people’s hearts and minds remain in the conversation. If solving equity issues were easy, we would have solved them by now. This will not be a conversation you can tie up in a neat bow. (para. 10)

Examining the beliefs and perceptions that fuel the structures and practices within schools should be at the forefront of teacher professional learning and teacher preparation efforts. This collective action and the evidence of impact facilitates collective efficacy; achieving collective efficacy within a system has the power to change lives (Donohoo, Hattie, & Eells, 2018).

The previous sections are overarching implications for the profession as a whole within the context of mathematics education; however, it is important to consider implications within the specific contexts of teacher preparation programs and teacher professional learning.

**Teacher preparation.** Teacher preparation programs provide a forum for identity work, especially within an elementary preservice setting. This type of identity work is inclusive of the multiple identities of the preservice teachers as well as their mathematical identity. Having preservice teachers write their mathematics autobiography at the beginning of a teacher preparation program, as well as at the end, would provide an opportunity for reflection and to identify growth over time. Additionally, engaging students in analyzing their own mathematics autobiography with an equity lens would provide the foundation for future reflective practices as they strive to create equitable experiences in their mathematics classrooms. Furthermore, as preservice teachers observe during their practicum experiences, an intentional focus on equity, using a framework such as the one presented in *Catalyzing Change* (2018), would provide an opportunity for preservice teachers to think critically about these complex issues in mathematics. This also creates a common focus for rich discussion within the mathematics teaching methods course that allows the instructor to engage the students in reflective questioning practices to deepen understanding and broaden perspectives.

**Professional learning.** Professional learning can be a means to develop the mathematical identities of teachers and to expand their perceptions of equity. Bianchini, Dweyer, Brenner, and Wearly (2015) conducted a study to examine professional learning strategies that aim to transform equity views and practices. The researchers identified four strategies: (1) teacher research, (2) personal reflection, (3) modeling productive instructional practices, and (4) examining data and concluded that all four strategies were beneficial to engage teachers in equity

talk (Bianchino, et al., 2015) and should be considered in light of the results of this study. As school districts and professional learning organizations engage in efforts to create more equitable experiences in mathematics, engaging in transformational professional learning would be an important goal.

This type of transformational professional learning addresses the whole teacher by expanding the focus beyond, knowledge, skills, and practices to include beliefs, emotions, and attitudes. This approach provides the space to address the mathematical identity of teachers and their perceptions of equity primarily through reflective coaching experiences. According to the International Literacy Association (2018), coaching for transformation engages teachers “in double-loop reflection and questions not only their own practice but also the historical power structures that operate within schools” (p. 5). Considering the results from this study, the researcher recommends a focus on affective development that includes a focus on the factors related to mathematical identity and perceptions of equity, particularly as it relates to the influence of the teacher.

### **Future Research**

Many questions were generated through this study. The following recommendations are provided for future research to support the productive development of mathematical identities and perception of equity:

1. As mentioned in the previous section, one of the participants commented on the benefits of participating in this study, thus creating an obvious future research question related to the impact of this type of reflective narrative process on preservice teachers’ understanding of their mathematical identity and perceptions of equity. In addition, understanding the growing

awareness of identity as a developmental process, as described by Jones and McEwen (2000), would add further depth to this line of research for both preservice and current educators.

2. Throughout the data are references to joy in mathematics, this along with NCTM's (2018) recommendation for cultivating wonder, joy, and beauty in mathematics make for an interesting focus. Current research in joy in mathematics is limited despite being associated with human flourishing (Watkins et al., 2017). According to Gutiérrez (2018), human flourishing is the goal of rehumanizing mathematics. Research pursuits that define joy in mathematics and establish the theoretical frameworks should be the primary focus. This is needed to provide the foundation and lens to examine the structures and practices that increase or diminish joy in mathematics.

3. Understanding true belonging in mathematics is associated with joy and human flourishing. According to Brown (2017),

True belonging is the spiritual practice of believing in and belonging to yourself so deeply that you can share your most authentic self with the world and find sacredness in both being a part of something and standing alone in the wilderness. True belonging doesn't require you to change who you are; it requires you to be who you are. (p. 40)

What does this mean in mathematics? How do we create wholehearted classrooms where everyone belongs so deeply that they also have the courage to stand alone? The data within this study suggest that the participants were negotiating the tension of belonging versus fitting in. They described experiences that made them feel both deeply connected and disconnected from mathematics. How these connections are formed and broken warrant further investigation.

These future research questions are in alignment with the *Mathematics Education Through the Lens of Social Justice: Acknowledgements, Actions, and Accountability* joint

position statement (NCSM & TODOS, 2016), which calls for a focus on empowerment. Within the notion of empowerment is the productive development of a student's mathematical identity. An understanding of reflective practices, joy, and true belonging in mathematics is a means to productively develop the mathematical identities of both teachers and students. This commitment to professionalism holds a mirror to our actions and creates bridges from our current state to our future state. Both mathematical identity and equity are complicated and complex issues and are worthy of the focus of scholars as well as the profession as a whole.

### **Conclusion**

Becoming is a lifelong process that is reflected in the stories we tell about who we are, who we are not, and who we intend to become (Aguirre et al., 2013). Our stories are a collection of significant moments that shape our beliefs and perceptions, so powerful they mediate how we engage or disengage in the world. Becoming implies a sense of empowerment. Within the context of mathematics, empowerment includes the notion of mathematical identity (Larson, 2016). Additionally, empowerment is associated with access and equity, and collectively all are necessary for people to fully realize their potential. Understanding how a mathematical identity is shaped, as a means to positively influence the development of equitable mathematics classrooms, was at the heart of this study. It is through this lens that this study examined the mathematical identity of eight preservice teachers and their perceptions of equity. People communicate who they are through the stories they tell themselves and others and within these stories "there's power in allowing yourself to be known and heard, in owning your unique story, in using your authentic voice. And there's grace in being willing to know and hear others. This, for me, is how we become" (Obama, 2018, p. 421).

## References

- Adler, J., Ball, D., Krainer, K., Lin, F. L., & Novotna, J. (2005). Reflections on an emerging field: Researching mathematics teacher education. *Educational Studies in Mathematics*, 60(3), 359-381.
- Aguirre, J., Mayfield-Ingram, K., & Martin, D. (2013). The impact of identity in K–8 mathematics: Rethinking equity-based practices. The National Council of Teachers of Mathematics. Reston, VA: The National Council of Teachers of Mathematics.
- Ainsworth, L. (2011). *Rigorous curriculum design: How to create curricular units of study that align standards, instruction, and assessment*. Boulder, CO: Lead+ Learn Press.
- Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation in Counseling and Development*, 22(3), 143–150.
- Ayob, A., & Yasin, R. M. (2017). Factors affecting attitudes towards mathematics. *International Journal of Academic Research in Business and Social Sciences*, 7(11), 1100–1109.
- Ball, D., (2017). Can teaching be a force for justice? Inaugural lecture of the Rutgers Graduate School of Education's Advancing Excellence and Equity in Education Distinguished Lecture Series, New Brunswick, NJ, November 2, 2017.
- Ball, D. L., & Forzani, F. M. (2010). What does it take to make a teacher? *Phi Delta Kappan*, 92(2), 8–12.
- Ball, D. L., & Forzani, F. (2011). Building a common core for learning to teach: And connecting professional learning to practice. *American Educator*. 35(2), 17



- Ball, D. L., Hill, H. C., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator*, 29(1), 14–17, 20–22, 43–46.
- Ball, D., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389–407.
- Ball, D. L. (2017). How can teaching be a force for justice? [PowerPoint Slides]. Retrieved from [https://static1.squarespace.com/static/577fc4e2440243084a67dc49/t/59fc993624a694793496c197/1509726521622/110217\\_Rutgers.pdf](https://static1.squarespace.com/static/577fc4e2440243084a67dc49/t/59fc993624a694793496c197/1509726521622/110217_Rutgers.pdf)
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191.
- Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, 28(2), 117–148.
- Bannister, N. A. (2016). Breaking the spell of differentiated instruction through equity pedagogy and teacher community. *Cultural Studies of Science Education*, 11(2), 335–347.
- Beauchamp, C., & Thomas, L. (2009). Understanding teacher identity: An overview of issues in the literature and implications for teacher education. *Cambridge Journal of Education*, 39(2), 175–189.
- Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences*, 107(5), 1860–1863.
- Biafora, F., & Ansalone, G. (2008). Perceptions and attitudes of school principals towards school tracking: Structural considerations of personal beliefs. *Education*, 128(4), 588–603.

- Bianchini, J. A., Dwyer, H. A., Brenner, M. E., & Wearly, A. J. (2015). Facilitating science and mathematics teachers' talk about equity: What are the strengths and limitations of four strategies for professional learning?. *Science Education*, 99(3), 577-610.
- Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. *Journal for Research in Mathematics Education*, 29(1), 41–62.
- Boaler, J. (1999). Participation, knowledge and beliefs: A community perspective on mathematics learning. *Educational Studies in Mathematics*, 40(3), 259–281.
- Boaler, J. (2002). Learning from teaching: Exploring the relationship between reform curriculum and equity. *Journal for Research in Mathematics Education*, 33(4), 239–258.
- Boaler, J. (2006). How a detracked mathematics approach promoted respect, responsibility, and high achievement. *Theory into Practice*, 45(1), 40–46.
- Boaler, J. (2008). Promoting 'relational equity' and high mathematics achievement through an innovative mixed-ability approach. *British Educational Research Journal*, 34(2), 167–194.
- Boaler, J. (2013, March). Ability and mathematics: The mindset revolution that is reshaping education. *Forum*, 55(1), 143–152).
- Boaler, J. (2014). Research suggests that timed tests cause math anxiety. *Teaching children mathematics*, 20(8), 469-474.
- Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages, and innovative teaching*. Hoboken, NJ: Wiley.

- Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing in mathematics worlds. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 171–200). Westport, CT: Ablex.
- Boaler, J., & Selling, S. K. (2017). Psychological imprisonment or intellectual freedom? A longitudinal study of contrasting school mathematics approaches and their impact on adults' lives. *Journal for Research in Mathematics Education*, 48(1), 78–105.
- Boaler, J., & Staples, M. (2008). Creating mathematical futures through an equitable teaching approach: The case of Railside School. *Teachers College Record*, 110(3), 608–645.
- Boaler, J., William, D., & Zevenbergen, R. (2000). *The construction of identity in secondary mathematics education*. Paper presented at the International Mathematics Education and Society Conference, Montechoro, Portugal, March 26-31, 2000.
- Briars, D. J., Larson, M., Strutchens, M. E., & Barnes, D. (2015). A call for mathematics education colleagues and stakeholders to collaboratively engage with NCTM: In response to Martin's commentary. *Journal of Urban Mathematics Education*, 8(2). Brown, B. (2017). *Braving the wilderness: The quest for true belonging and the courage to stand alone*. New York.
- Brown, B. (2010, June). *The power of vulnerability*. [Video file]. Retrieved from [https://www.ted.com/talks/brene\\_brown\\_on\\_vulnerability#t-107639](https://www.ted.com/talks/brene_brown_on_vulnerability#t-107639)
- Brown, B. (2015). *Rising strong: How the ability to reset transforms the way we live, love, parent, and lead*. New York, NY: Random House.
- Brown, B. (2017). *Braving the wilderness: The quest for true belonging and the courage to stand alone*. New York: Random House. Bruner, J. (1987). Life as narrative. *Social Research*, 54(1), 11–32.

- Bruner, J. (1987). Life as narrative. *Social research*, 11-32.
- Bruner, J. (2004). Life as narrative. *Social Research: An International Quarterly*, 71(3), 691–710.
- Butz, A. R., & Usher, E. L. (2015). Salient sources of early adolescents' self-efficacy in two domains. *Contemporary Educational Psychology*, 42, 49–61.
- Chen, J. Q., & Chang, C. (2006). Testing the "Whole Teacher" Approach to Professional Development: A Study of Enhancing Early Childhood Teachers' Technology Proficiency. *Early Childhood Research & Practice*, 8(1), n1.
- Cimpian, J. R., Lubienski, S. T., Timmer, J. D., Makowski, M. B., & Miller, E. K. (2016). Have gender gaps in math closed? Achievement, teacher perceptions, and learning behaviors across two ECLS-K cohorts. *AERA Open*, 2(4). doi: 2332858416673617.
- Clandinin, D. J., & Connelly, F. M. (2000). *Narrative inquiry: Experience and story in qualitative research*. San Francisco, CA: Jossey-Bass.
- Clark, L. M., DePiper, J. N., Frank, T. J., Nishio, M., Campbell, P. F., Smith, T. M., ... & Choi, Y. (2014). Teacher characteristics associated with mathematics teachers' beliefs and awareness of their students' mathematical dispositions. *Journal for Research in Mathematics Education*, 45(2), 246-284.
- Clements, D. H., & Battista, M. T. (1990). Constructivist learning and teaching. *Arithmetic Teacher*, 38(1), 34–35.
- Clements, D. H., & Sarama, J. (2011). Early childhood teacher education: The case of geometry. *Journal of Mathematics Teacher Education*, 14(2), 133–148.
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage.

- Creswell, J., & Poth, C. (2018). *Qualitative inquiry & research design: Choosing among five approaches* (4th ed.). Los Angeles: Sage.
- Cribbs, J. D., Hazari, Z., Sonnert, G., & Sadler, P. M. (2015). Establishing an explanatory model for mathematics identity. *Child Development*, 86(4), 1048–1062.
- Darling-Hammond, L. (2000). Teacher quality and student achievement. *Education Policy Analysis Archives*, 8, 1.
- Darling-Hammond, L. (2015). *The flat world and education: How America's commitment to equity will determine our future*. Teachers College Press.
- Daro, P., McCallum, B., & Zimba, J. (2012). The structure is the standards [Blog]. Retrieved from [www.commoncoretools.me](http://www.commoncoretools.me), 2, 16.
- Darragh, L. (2013). Constructing confidence and identities of belonging in mathematics at the transition to secondary school. *Research in Mathematics Education*, 15(3), 215–229.
- Darragh, L. (2016). Identity research in mathematics education. *Educational Studies in Mathematics*, 93(1), 19–33.
- Denzin, N. K., & Lincoln, Y. S. (Eds.). (2018). *The Sage handbook of qualitative research*. Thousand Oaks, CA: Sage.
- Di Martino, P. (2016). Attitudes, beliefs, motivation, and identity in mathematics education. In *Attitudes, Beliefs, Motivation and Identity in Mathematics Education* (pp. 2–6). New York, NY: Springer.
- Di Martino, P., & Zan, R. (2010). ‘Me and maths’: Towards a definition of attitude grounded on students’ narratives. *Journal of Mathematics Teacher Education*, 13(1), 27–48.
- Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM*, 43(4), 471–482.

- Donaldson, S. I., Dollwet, M., & Rao, M. A. (2015). Happiness, excellence, and optimal human functioning revisited: Examining the peer-reviewed literature linked to positive psychology. *Journal of Positive Psychology, 10*(3), 185–195.
- Donohoo, J., Hattie, J., & Eells, R. (2018). The power of collective efficacy. *Educational Leadership, 75*(6), 40–44.
- Drake, C., Spillane, J. P., & Hufferd-Ackles, K. (2001). Storied identities: Teacher learning and subject-matter context. *Journal of Curriculum Studies, 33*(1), 1–23.
- Educational Policy Improvement Center. (2014). National Assessment of Educational Progress and 12th grade preparedness research college course content analysis study final report. Eugene, OR: Author.
- Ernest, P. (1989). The knowledge, beliefs and attitudes of the mathematics teacher: A model. *Journal of Education for Teaching, 15*(1), 13–33.
- Flores, A. (2007). Examining disparities in mathematics education: Achievement gap or opportunity gap? *High School Journal, 91*(1), 29–42.
- Frade, C., & Meira, L. (2010). The social nature of affective behaviors and the constitution of identity. In Identity and affect in the context of teachers' professional development. In M. M. F. Pinto & T. F. Kawasaki (Eds.), *Proceedings of the 34th Conference for the International Group for the Psychology of Mathematics Education* (Vol. 1, pp. 247–249).
- Frade, C., Roesken, B., & Hannula, M. S. (2010). Identity and affect in the context of teachers' professional development. In *Proceedings of the 34th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 1, pp. 247–279). Belo Horizonte, Brazil: PME.

- Fredrickson, B.L. (2003). The value of positive emotions. The emerging science of positive psychology is coming to understand why it's good to feel good. *American Scientist*, 91(4), 330-335.
- Fredrickson, B. L. (2013). Positive emotions broaden and build. *In Advances in experimental social psychology* (Vol. 47, pp. 1-53). Academic Press.
- Frenzel, A. C., Goetz, T., Pekrun, R., & Watt, H. M. (2010). Development of mathematics interest in adolescence: Influences of gender, family, and school context. *Journal of Research on Adolescence*, 20(2), 507–537.
- Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700.
- Goodson, I., & Sikes, P. (2001). *Life history research in educational settings: Learning from lives* (Doing qualitative research in educational settings). Buckingham, UK: Open University Press.
- Gresalfi, M., Martin, T., Hand, V., & Greeno, J. (2009). Constructing competence: An analysis of student participation in the activity systems of mathematics classrooms. *Educational Studies in Mathematics*, 70(1), 49–70.
- Grootenboer, P., Smith, T., & Lowrie, T. (2006). Researching identity in mathematics education: The lay of the land. *Identities, Cultures and Learning Spaces*, 2, 612–615.
- Grootenboer, P., & Zevenbergen, R. (2008). Identity as a lens to understand learning mathematics: Developing a model. *Navigating currents and charting directions*, 1, 243–250.
- Guba, E. G. (Ed.). (1990). *The paradigm dialog*. Thousand Oaks, CA: Sage.

- Gujarati, J. (2010). *Portraits of early career elementary teachers: Examining beliefs about mathematics in the midst of classroom practices*. New York: Teachers College, Columbia University.
- Gujarati, J. (2013). An “inverse” relationship between mathematics identities and classroom practices among early career elementary teachers: The impact of accountability. *Journal of Mathematical Behavior*, 32(3), 633–648.
- Gutiérrez, R. (2008). A “gap-gazing” fetish in mathematics education? Problematizing research on the achievement gap. *Journal for Research in Mathematics Education*, 39(4), 357–364.
- Gutiérrez, R. (2013). The sociopolitical turn in mathematics education. *Journal for Research in Mathematics Education*, 44(1), 37–68.
- Gutiérrez, R. (2018). Rehumanizing mathematics: A vision for the future [video file]. Retrieved from <https://www.youtube.com/watch?v=D266LYIigS0>
- Haberman, M. (1991). The pedagogy of poverty versus good teaching. *Phi Delta Kappan*, 73(4), 290–294.
- Haberman, M. (2010). The pedagogy of poverty versus good teaching. *Phi Delta Kappan*, 92(2), 81–87.
- Haberman, M., Gillette, M. D., & Hill, D. A. (2018). *Star teachers of children in poverty*. New York, NY: Routledge.
- Hargreaves, A., & Fullan, M. (2013). The power of professional capital: With an investment in collaboration, teachers become nation builders. *Journal of Staff Development*, 34(3), 36–39.



- Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge.
- Hayes-Jacobs, H. (Ed.). (2010). *Curriculum 21: Essential education for a changing world*. ASCD.
- Heath, C., & Heath, D. (2010). *Switch: How to change when change is hard*. New York, NY: Random House.
- Heyd-Metzuyanim, E., Lutovac, S., & Kaasila, R. (2016). Attitudes, beliefs, motivation, and identity in mathematics education. In *Attitudes, Beliefs, Motivation and Identity in Mathematics Education* (pp. 1–35). New York, NY: Springer.
- Hill, H. C., & Ball, D. L. (2004). Learning mathematics for teaching: Results from California's mathematics professional development institutes. *Journal for Research in Mathematics Education*, 35(5), 330–351.
- Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, 372-400.
- Hill, H. C., Schilling, S. G., & Ball, D. L. (2004). Developing measures of teachers' mathematics knowledge for teaching. *The elementary school journal*, 105(1), 11-30.
- Hodgen, J., & Askew, M. (2007). Emotion, identity and teacher learning: Becoming a primary mathematics teacher. *Oxford Review of Education*, 33(4), 469-487.
- Howard, T. C. (2010). *Why race and culture matter in schools: Closing the achievement gap in America's classrooms* (Vol. 39). New York, NY: Teachers College Press.

- Howard, T. C. (2018). Dismantling the equity problem one conversation at a time [web log comment]. Retrieved from <https://www.hmhco.com/blog/dismantling-the-equity-problem-one-conversation-at-a-time>
- International Literacy Association. (2018). *Literacy coaching for change: Choices matter*. [Literacy leadership brief]. Newark, DE: Author.
- Jones, S. R., & McEwen, M. K. (2000). A conceptual model of multiple dimensions of identity. *Journal of College Student Development*, 41(4), 405–414.
- Jong, C. (2016). Linking reform-oriented experiences to teacher identity: The case of an elementary mathematics teacher. *Journal of Educational Research*, 109(3), 296–310.
- Kaasila, R. (2007). Mathematical biography and key rhetoric. *Educational Studies in Mathematics*, 66(3), 373–384.
- Kutaka, T. S., Ren, L., Smith, W. M., Beattie, H. L., Edwards, C. P., Green, J. L., . . . & Lewis, W. J. (2016). Examining change in K–3 teachers’ mathematical knowledge, attitudes, and beliefs: the case of Primarily Math. *Journal of Mathematics Teacher Education*, 21(2), 144–177.
- Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, 32(3), 465–491.
- Ladson-Billings, G. (1997). It doesn’t add up: African American students’ mathematics achievement. *Journal for Research in Mathematics Education*, 28(6), 697–708.
- Ladson-Billings, G. (2014). Culturally relevant pedagogy 2.0: aka the remix. *Harvard Educational Review*, 84(1), 74–84.
- Lake, V. E., & Kelly, L. (2014). Female preservice teachers and mathematics: Anxiety, beliefs, and stereotypes. *Journal of Early Childhood Teacher Education*, 35(3), 262–275.

- Larson, M. (2016). A renewed focus on access, equity, and empowerment. National Council of Teachers of Mathematics. Retrieved from <https://www.nctm.org/News-and-Calendar/Messages-from-the-President/Archive/Matt-Larson/A-Renewed-Focus-on-Access,-Equity,-and-Empowerment/>
- Larson, M. (2017). A Perfect Storm of Data: We Must Take Action! Retrieved from [http://www.nctm.org/News-and-Calendar/Messages-from-the-President/Archive/Matt-Larson/A-Perfect-Storm-of-Data-We-Must-Take-Action!/?](http://www.nctm.org/News-and-Calendar/Messages-from-the-President/Archive/Matt-Larson/A-Perfect-Storm-of-Data-We-Must-Take-Action!/)
- Latterell, C., & Wilson, J. (2016). Stories about math: An analysis of students' math autobiographies. *International Journal of Research in Education and Science*, 2(2), 279–285.
- Latterell, C. M., & Wilson, J. L. (2017). Metaphors and mathematical identity: Math is like a tornado in Kansas. *Journal of Humanistic Mathematics*, 7(1), 46-61.
- Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge University Press.
- Lazarides, R., & Ittel, A. (2013). Mathematics interest and achievement: What role do perceived parent and teacher support play? A longitudinal analysis. *International Journal of Gender, Science and Technology*, 5(3), 207–231.
- Liljedahl, P., & Hannula, M. S. (2016). Research on mathematics-related affect. In *the Second Handbook of Research on the Psychology of Mathematics Education* (pp. 417–446). Rotterdam, the Netherlands. Sense.
- Lincoln, Y. S., Lynham, S. A., & Guba, E. G. (2018). Paradigmatic controversies, contradictions, and emerging confluences, revisited. *The Sage handbook of qualitative research*, 5, 108–150.

- Lui, A. M., & Bonner, S. M. (2016). Preservice and inservice teachers' knowledge, beliefs, and instructional planning in primary school mathematics. *Teaching and Teacher Education*, 56, 1–13.
- Lutovac, S., & Kaasila, R. (2011). Beginning a pre-service teacher's mathematical identity work through narrative rehabilitation and bibliotherapy. *Teaching in Higher Education*, 16(2), 225–236.
- Lutovac, S., & Kaasila, R. (2014). Pre-service teachers' future-oriented mathematical identity work. *Educational Studies in Mathematics*, 85(1), 129–142.
- Ma, J. Y., & Singer-Gabella, M. (2011). Learning to teach in the figured world of reform mathematics: Negotiating new models of identity. *Journal of Teacher Education*, 62(1), 8–22.
- Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Ma, L. (2010). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. New York, NY: Routledge.
- Maasepp, B., & Bobis, J. (2015). Prospective primary teachers' beliefs about mathematics. *Mathematics Teacher Education and Development*, 16(2), 89–107.
- Marshall, C., & Rossman, G. B. (2016). *Designing qualitative research*. Thousand Oaks, CA: Sage.
- Martin, D. B. (2015). The Collective Black and “Principles to Actions.” *Journal of Urban Mathematics Education*, 8(1), 17–23.

- Martínez, F., Martínez, S., & Mizala, A. (2015). Pre-service Elementary School Teachers' Expectations about Student Performance: How their beliefs are affected by their mathematics anxiety and student's gender (No. 310).
- Maxwell, J. A. (2013). *Qualitative research design: An interactive approach* (Vol. 41). Thousand Oaks, CA: Sage
- McCray, J. S., & Chen, J.-Q. (2012). Pedagogical content knowledge for preschool mathematics: Construct validity of a new teacher interview. *Journal of Research in Childhood Education, 26*(3), 291–307.
- McCulloch, A. W., Marshall, P. L., DeCuir-Gunby, J. T., & Caldwell, T. S. (2013). Math autobiographies: A window into teachers' identities as mathematics learners. *School Science and Mathematics, 113*(8), 380-389.
- McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. *Handbook of Research on Mathematics Teaching and Learning, 575–596*. New York, NY: Macmillan.
- Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. San Francisco, CA: Jossey-Bass.
- Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation*. Hoboken, NJ: Wiley.
- Miranda, L. (2016). Hamilton: An American musical. In J. McCarter (Ed.), *Hamilton: The revolution* (pp. 23–26). New York, NY: Grand Central Publishing.
- Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics*. TIMSS & PIRLS International Study Center at Boston College.

- Murphy, M. C., & Dweck, C. S. (2010). A culture of genius: How an organization's lay theory shapes people's cognition, affect, and behavior. *Personality and Social Psychology Bulletin*, 36(3), 283–296.
- Nakhid, C. (2012). 'Which side of the bridge to safety?' How young Pacific Islanders in New Zealand view their South Auckland community. *Kotuitui: New Zealand Journal of Social Sciences Online*, 7(1), 14–25.
- Nasir, N. I. S., & de Royston, M. M. (2013). Power, identity, and mathematical practices outside and inside school. *Journal for Research in Mathematics Education*, 44(1), 264–287.
- Nasir, N. I. S., & Hand, V. M. (2006). Exploring sociocultural perspectives on race, culture, and learning. *Review of Educational Research*, 76(4), 449–475.
- National Assessment of Educational Progress. (2015). Washington DC: National Center for Education Statistics. Retrieved from <https://nces.ed.gov/nationsreportcard/>
- National Assessment of Educational Progress. (2017). Washington DC: National Center for Education Statistics. Retrieved from <https://nces.ed.gov/nationsreportcard/>
- National Council of Supervisors of Mathematics (NCSM) & TODOS: Mathematics for ALL. (2016). Mathematics education through the lens of social justice: Acknowledgment, actions, and accountability. (Joint position statement). Retrieved from [http://www.todos-math.org/assets/docs2016/2016Enews/3.pospaper16\\_wtodos\\_8pp.pdf](http://www.todos-math.org/assets/docs2016/2016Enews/3.pospaper16_wtodos_8pp.pdf)
- National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- National Council of Teachers of Mathematics (NCTM). (2012). Closing the opportunity gap in mathematics education. (Position statement). Retrieved from [https://www.nctm.org/uploadedFiles/Standards\\_and\\_Positions/Position\\_](https://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_)

Statements/Opportunity%20Gap.pdf

- National Council of Teachers of Mathematics (NCTM). (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: National Council of Teachers of Mathematics.
- National Council of Teachers of Mathematics (NCTM). (2018). *Catalyzing change in high school mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- National Governors Association Center for Best Practices and Council of Chief State School Officers. *Common Core State Standards for Mathematics*. Washington, D.C.: NGA Center and CCSSO, 2010. <http://www.corestandards.org>.
- National Assessment of Educational Progress. (2015) Washington DC: National Center for Education Statistics. Retrieved from <https://nces.ed.gov/nationsreportcard/>
- National Assessment of Educational Progress. (2017) Washington DC: National Center for Education Statistics. Retrieved from <https://nces.ed.gov/nationsreportcard/>
- Obama, M., (2018) *Becoming*. New York: Crown.
- Organisation for Economic Co-operation and Development (OECD). (2018). *PISA 2015 Results in action*. Paris: Author.
- Ortony, A., Clore, G. L., & Foss, M. A. (1987). The referential structure of the affective lexicon. *Cognitive Science*, 11(3), 341–364.
- Packer, M. J., & Goicoechea, J. (2000). Sociocultural and constructivist theories of learning: Ontology, not just epistemology. *Educational Psychologist*, 35(4), 227–241.
- Park, V., & Datnow, A. (2017). Ability grouping and differentiated instruction in an era of data-driven decision making. *American Journal of Education*, 123(2), 281-306.
- Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher*, 41(3), 93–97.

- Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. Second handbook of research on mathematics teaching and learning, 257-315. Reston, VA: National Council of Teachers of Mathematics.
- PISA, O. (2015). Results in focus. <http://www.oecd.org/pisa/keyfindings/pisa-2015-results-overview.pdf>.
- Radovic, D., Black, L., Salas, C. E., & Williams, J. (2017). Being a girl mathematician: Diversity of positive mathematical identities in a secondary classroom. *Journal for Research in Mathematics Education*, 48(4), 434–464.
- Ramirez, G., Hooper, S. Y., Kersting, N. B., Ferguson, R., & Yeager, D. (2018). Teacher math anxiety relates to adolescent students' math achievement. *AERA Open*, 4(1). doi: 2332858418756052.
- Rattan, A., Good, C., & Dweck, C. S. (2012). “It’s ok—Not everyone can be good at math”: Instructors with an entity theory comfort (and demotivate) students. *Journal of Experimental Social Psychology*, 48(3), 731–737.
- Raymond, A. M. (1997). Inconsistency between a beginning elementary school teacher's mathematics beliefs and teaching practice. *Journal for Research in Mathematics Education*, 550-576.
- Reeves, D. (2011). Elements of grading: A guide to effective practice. Bloomington, IN: Solution Tree Press.
- Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of Research on Teacher Education* (2nd ed.) (pp. 102–119). New York, NY: Macmillan.



- Salikutluk, Z., & Heyne, S. (2017). Do gender roles and norms affect performance in maths? The impact of adolescents' and their peers' gender conceptions on maths grades. *European Sociological Review*, 33(3), 368-381.
- Sanders, W. L., Wright, S. P., & Horn, S. P. (1997). Teacher and classroom context effects on student achievement: Implications for teacher evaluation. *Journal of Personnel Evaluation in Education*, 11(1), 57-67.
- Schoenfeld, A. H. (1999). Models of the teaching process. *Journal of Mathematical Behavior*, 18(3), 243-261.
- Schwandt, T. A., & Gates, E. F. (2018). Case study methodology. In *The Sage handbook of qualitative research* (pp. 341-358).
- Seeley, C. L. (2015). *Faster isn't smarter: messages about math, teaching, and learning in the 21st century: a resource for teachers, leaders, policy makers, and families*. (2<sup>nd</sup> ed.). Sausalito, CA: Math Solutions.
- Sfard, A., & Prusak, A. (2005a). Identity that makes a difference: Substantial learning as closing the gap between actual and designated identities. *International Group for the Psychology of Mathematics Education*, 1, 37-52.
- Sfard, A., & Prusak, A. (2005b). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher*, 34(4), 14-22.
- Shaver, P., Schwartz, J., Kirson, D., & O'Connor, C. (1987). Emotion knowledge: Further exploration of a prototype approach. *Journal of Personality and Social Psychology*, 52(6), 1061.
- Shkedi, A. (2005). *Multiple case narrative: A qualitative approach to studying multiple populations* (Vol. 7). Philadelphia, PA: John Benjamins Publishing.

- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.
- Shulman, L. S. (2013). Those who understand: Knowledge growth in teaching. *Journal of Education*, 193(3), 1–11.
- Spillane, J. P. (2000). A fifth-grade teacher's reconstruction of mathematics and literacy teaching: Exploring interactions among identity, learning, and subject matter. *Elementary School Journal*, 100(4), 307–330.
- Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.
- Stinson, D. W. (2004). Mathematics as “gate-keeper”: Three theoretical perspectives that aim toward empowering all children with a key to the gate. Conference of the Mathematics Education Research Group of Australasia (Vol. 2, pp. 799–806).
- Stoehr, K. J. (2015). *Building the wall brick by brick: One prospective teacher's experiences with mathematics anxiety*. *Journal of Mathematics Teacher Education*, 20(2), 119–139.
- Stoehr, K. J. (2017). Mathematics anxiety: One size does not fit all. *Journal of Teacher Education*, 68(1), 69–84.
- Taie, S., & Goldring, R. (2017). Characteristics of public elementary and secondary school teachers in the United States: Results from the 2015–16 National Teacher and Principal Survey. First Look. NCES 2017-072. Washington, DC: National Center for Education Statistics.
- Thompson, A. G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics*, 15(2), 105–127.

- Wager, A. A., & Foote, M. Q. (2013). Locating praxis for equity in mathematics: Lessons from and for professional development. *Journal of Teacher Education*, 64(1), 22–34.
- Walshaw, M. (2007). *Working with Foucault in education*. Rotterdam, the Netherlands. Sense.
- Walshaw, M. (2011). *Mapping equity and quality in mathematics education*. New York, NY: Springer.
- Walshaw, M. (2013). Post-structuralism and ethical practical action: Issues of identity and power. *Journal for Research in Mathematics Education*, 44(1), 100–118.
- Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational psychology review*, 29(1), 119-140.
- Watkins, P. C., Emmons, R. A., Greaves, M., & Bell, J. (2017). Assessment of Joy and Relationship to Gratitude and Well-being. 1-54.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.
- Werblow, J., Urick, A., & Duesbery, L. (2013). On the wrong track: How tracking is associated with dropping out of high school. *Equity & Excellence in Education*, 46(2), 270–284.
- Wimer, J. W., Ridenour, C. S., Thomas, K., & Place, A. W. (2001). Higher order teacher questioning of boys and girls in elementary mathematics classrooms. *Journal of Educational Research*, 95(2), 84–92.
- Woodward, J., & Irwin, K. (2005). Language appropriate for the New Zealand numeracy project. In *Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia* (Vol. 2, pp. 799–806).

- Yazan, B. (2015). Three approaches to case study methods in education: Yin, Merriam, and Stake. *The Qualitative Report*, 20(2), 134–152.
- Yin, R. K. (2014). *Case study research: Design and methods*. Thousand Oaks, CA: Sage.
- Young, M., & Muller, J. (2013). On the powers of powerful knowledge. *Review of Education*, 1(3), 229–250.

## Appendix A

Participant recruitment email:

My name is Meaghan Pavlovich, and I'm a doctoral student working to complete my dissertation research this semester. My study is focused on mathematical identity as a way to influence equity within mathematics.

I'm looking for KU students from your class to participate in my study. For this study, I would ask you to meet with me 3 times, over the next 2 months, for a total of 2 hours. I will work with your class and field schedule to make meetings convenient for you. The focus of the conversation during these meetings is related to your mathematics autobiography.

If you are interested in participating, please send an email to [mpavlovich@ku.edu](mailto:mpavlovich@ku.edu).

I will be in [REDACTED] class on September 25th to introduce myself and to meet with those of you who have agreed to participate.

Many thanks,  
Meaghan Pavlovich

## Appendix B

### Preservice Teacher Informed Consent Statement

A Qualitative Case Study: Understanding the Mathematical Identity of Preservice Teachers

The [university] supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the [university].

#### PURPOSE OF THE STUDY

The purpose of the study is to explore the mathematical identity of preservice teachers while enrolled in both [courses].

#### PROCEDURES

As a participant in this study you will be asked to:

- Provide a mathematics autobiography to be used as data for this study.
- To be interviewed on three separate occasion. The audio of each interview will be recorded using an iPad and iPhone through the Rev transcription application. Rev will provide a verbatim transcription that will be sent via email to the researcher. The transcript will be stored on a password protected computer in a password protected qualitative analysis software program. You may stop recording at any time during the interview. These recordings are required to participate in the study as they serve as a primary source of data.
  - During the first interview, lasting approximately 30 minutes, you will be asked to retell your mathematics autobiography.
  - The second interview will be a longer interview, approximately 60 minutes, where the researcher will ask you questions related to your relationship with mathematics.
  - The final interview will be an opportunity to review the initial findings of the study to ensure accuracy from your perspective.

#### RISKS AND BENEFITS

I understand that this method of data collection is not expected to interfere with my learning. No risks are anticipated for participating in this study. Participating in this study may help me to think about my mathematical identity as I transition to becoming a teacher of mathematics. **I understand that it is not mandatory for me to participate in this study. Although writing a mathematics autobiography is mandatory assignment for [course], the data collected from this assignment will not affect my grade.**

Participation in this study will require a 2-hour time commitment in approximately a 6-week time span during the semester.

## PAYMENT TO PARTICIPANTS

Participants will not be paid to participate in this study.

## PARTICIPANT CONFIDENTIALITY

Your name will not be associated in any publication or presentation with the information collected about you or with the research findings from this study. Instead, the researcher(s) will use a study number or a pseudonym rather than your name. Your identifiable information will not be shared unless (a) it is required by law or university policy, or (b) you give written permission. Data will be stored on password protected devices and in a locked file box. Only the researcher and [advisor], the researcher's advisor will have access to the data. The data will be transcribed by Rev.com. The data will be kept for three years to ensure a thorough analysis and then destroyed.

## REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the [university] or to participate in any programs or events of the [university]. However, if you refuse to sign, you cannot participate in this study.

## CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose further information collected about you, in writing, at any time, by sending your written request to: [contact information for the researcher and advisor]

If you cancel permission to use your information, the researchers will stop collecting additional information about you. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

## QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s) listed at the end of this consent form.

**PARTICIPANT CERTIFICATION:**

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or (785) 864-7385, write the Human Research Protection Program (HRPP), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email [irb@ku.edu](mailto:irb@ku.edu).

I agree to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

---

Type/Print Participant's Name

---

Date

---

Participant's Signature

Researcher Contact Information

[contact information for the researcher]



## **Appendix C**

### **Unstructured Interview Questions**

Tell me about yourself and who you are.

Tell me about your personal history with mathematics starting with your earliest memory.

## Appendix D

### Semistructured Interview Questions

Research Questions	Interview Questions
1. How do beliefs about competence and performance shape the mathematical identity of preservice teachers?	1. How do you feel about learning mathematics? What makes you feel this way? 2. How confident are you learning in mathematics? What makes you feel this way? 3. How do you feel about teaching mathematics? What makes you feel this way? 4. How confident are you teaching in mathematics? What makes you feel this way? 5. What role does intelligence play in mathematics?
2. How do beliefs about recognition develop and how does that shape the mathematical identity of preservice teachers?	6. How do you think other people see you related to mathematics? 7. Tell me about a time when your mathematical ability was recognized. 8. Tell me about a time when your mathematical ability was not recognized.
3. How does interest develop and how does that shape the mathematical identity of preservice teachers?	9. How would you describe mathematics? 10. What purpose does mathematics serve? 11. Have you ever had negative feelings about math? What were those feelings? Why did you feel that way? Can you describe the experience?

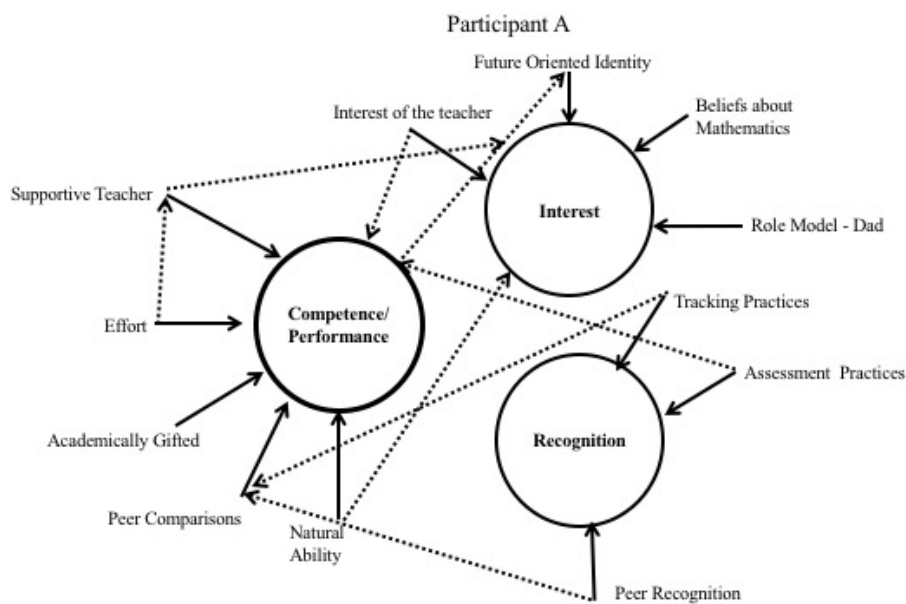
	Have you ever had positive feelings about math? What were those feelings? Why did you feel that way? Can you describe the experience?
4. How do perceptions of equity develop and how does that shape the mathematical identities of preservice teachers?	<p>12. How would you describe your core sense of self?</p> <p>13. How would you describe your various identities?</p> <p>14. How do you think your various identities will influence your students?</p> <p>15. How would you describe your mathematical identity?</p> <p>16. How do you think your mathematical identity will influence your students?</p> <p>17. How would you describe equity in mathematics?</p>

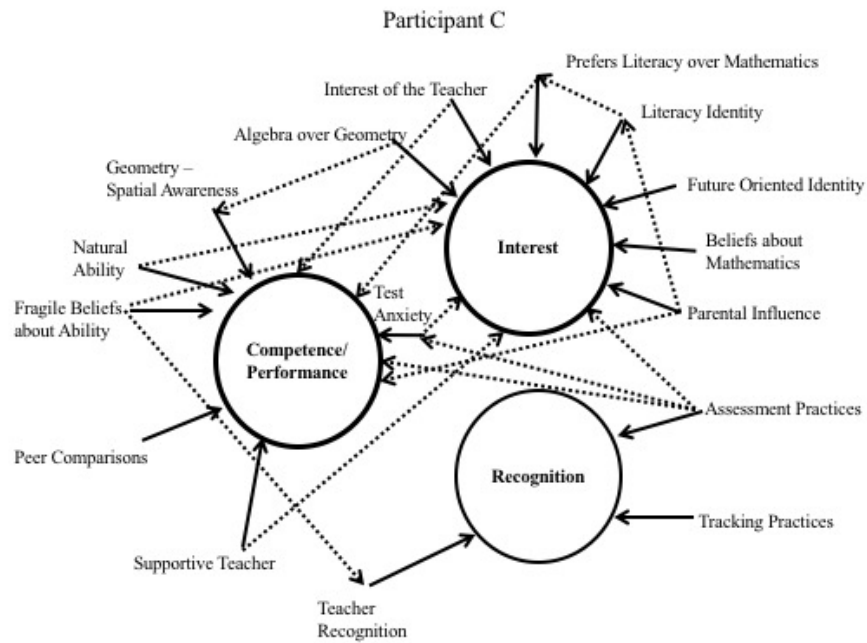
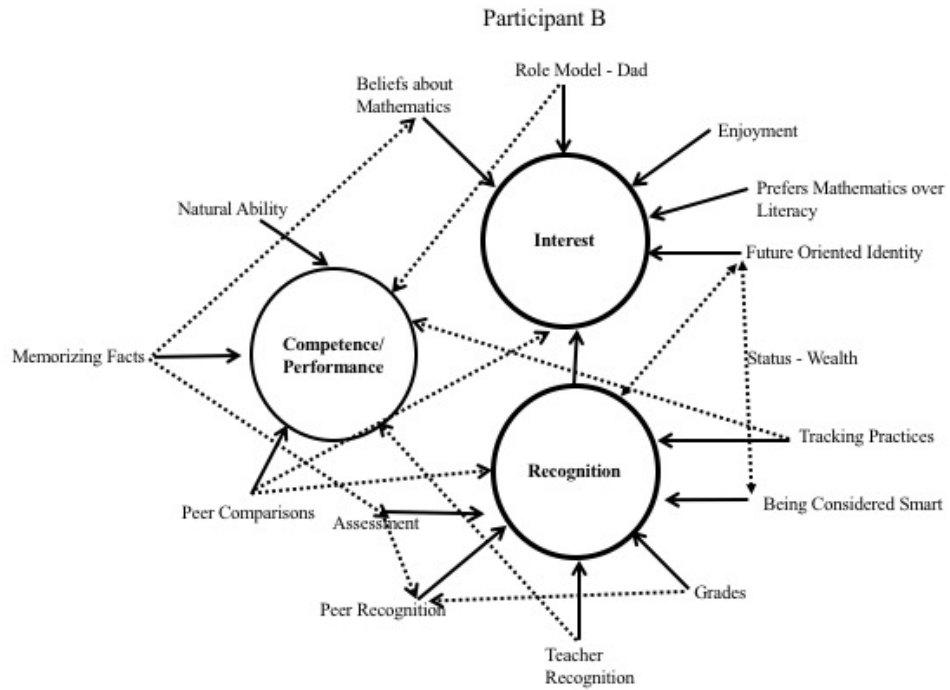
### Appendix E

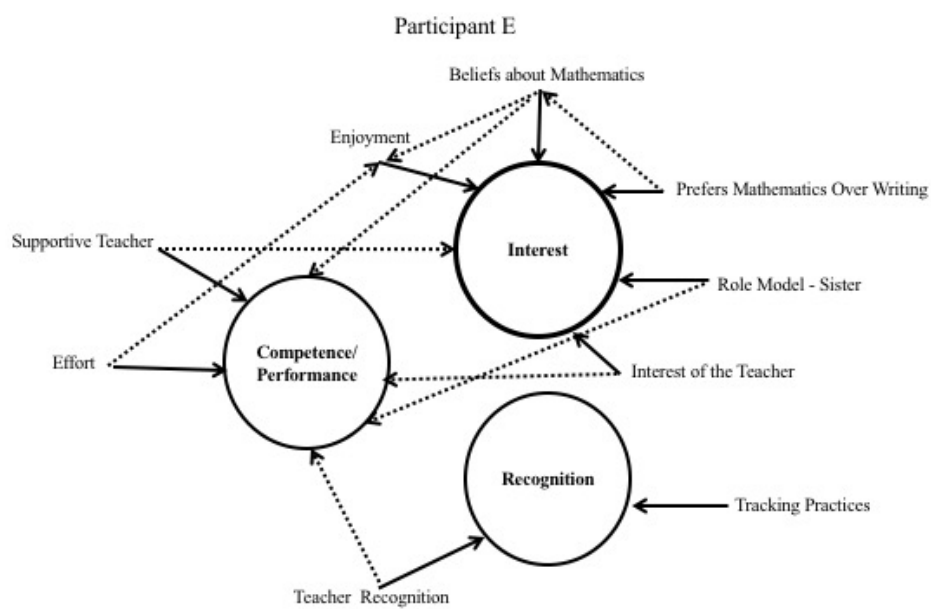
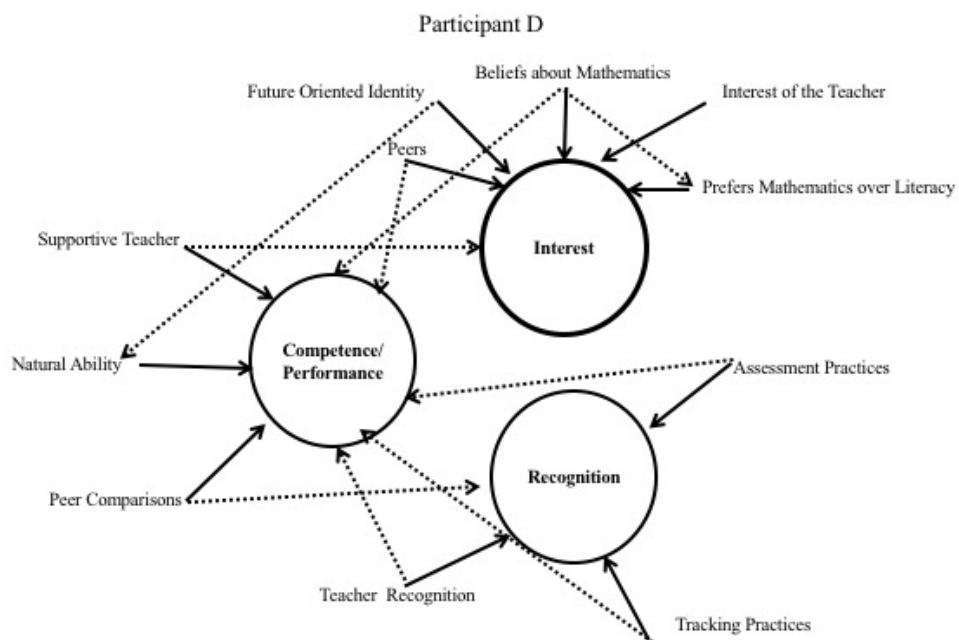
<b>Data Collection Plan</b>			
<b>Date</b>	<b>Participant</b>	<b>Activity</b>	<b>Time Needed</b>
October	A–H	Unstructured Interviews	30 minutes each
October	A–H	Transcribe Unstructured Interviews	2 days
October	A–H	Open Code Unstructured Interviews	14 days
October	A–H	Open Code Mathematics Autobiographies	14 days
October – November	A–H	Semistructured Interviews	60 minutes each
November	A–H	Transcribe Semistructured Interviews	2 days
November	A–H	Open Code Semistructured Interviews	10 days
November – December	A–H	Determine Categories and Code Unstructured Interviews, Semistructured Interviews, and Mathematics Autobiographies	16 days
December	A–H	Member Check Focus Group	30 minutes
December	A–H	Revise Data Based on Participant Feedback	2 days

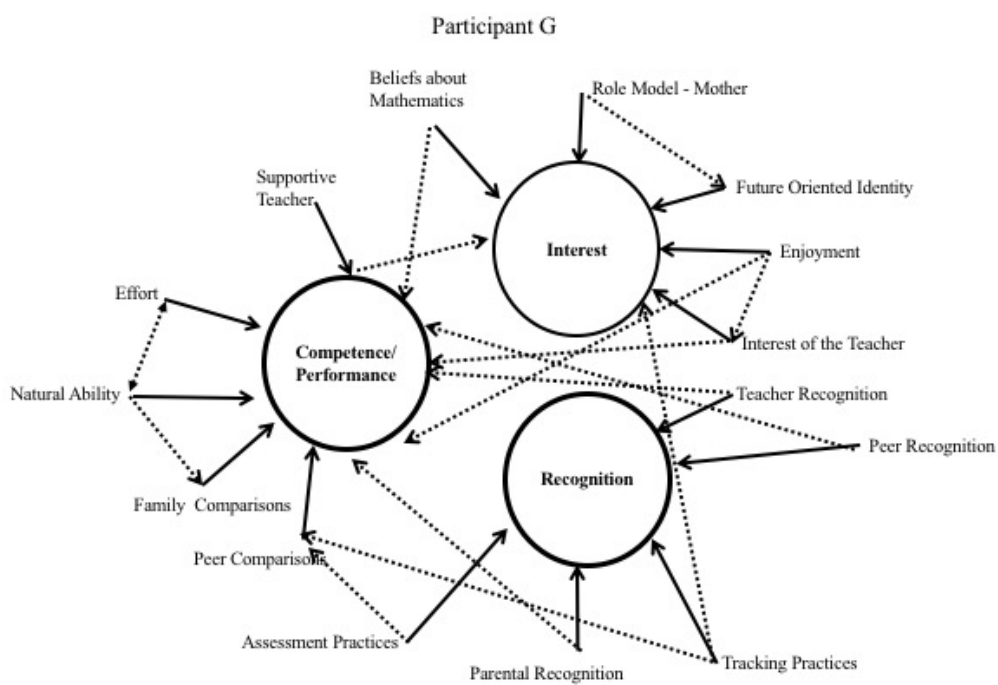
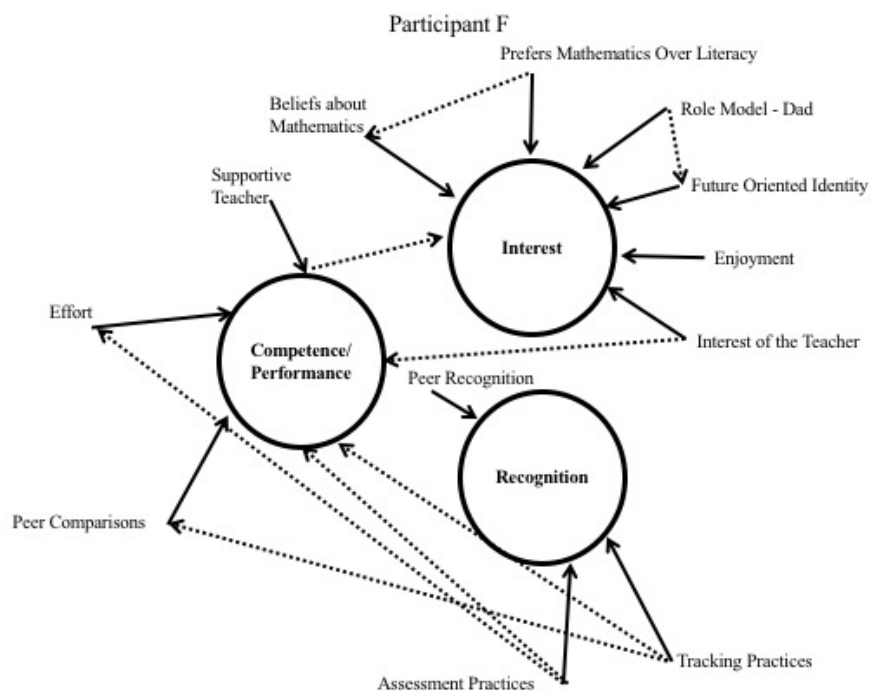
## Appendix F

The model for mathematics identity (Cribbs et al., 2015) that served as a conceptual framework was used to trace the relationships the participants described between the categories and themes. The results of this study expand upon the results of Cribbs et al. (2015) as the factors of competence and performance, recognition, and interest were identified as the categories that were identified from the data related to mathematical identity. The following models represent each of the individual participant's mathematical identity, as determined by the data maps that were created from the relationships between the categories and themes for each participant. The bolded categories and arrows represent a more prominent presence in the data thus suggesting a stronger influence on the mathematical identity of the participant. The dashed arrows represent the relationship between the categories and themes.

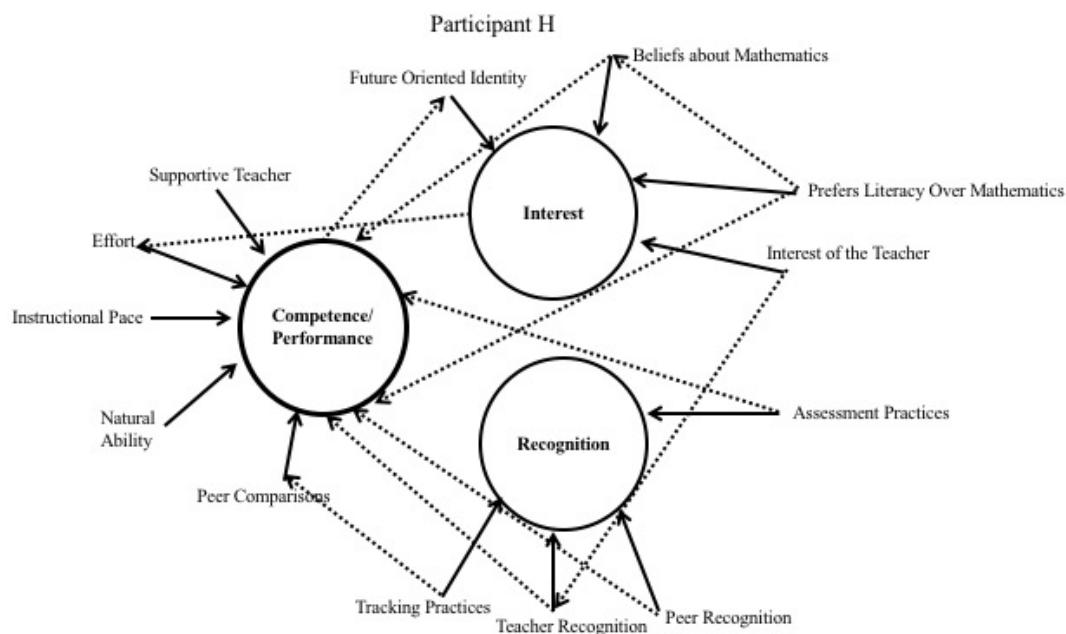




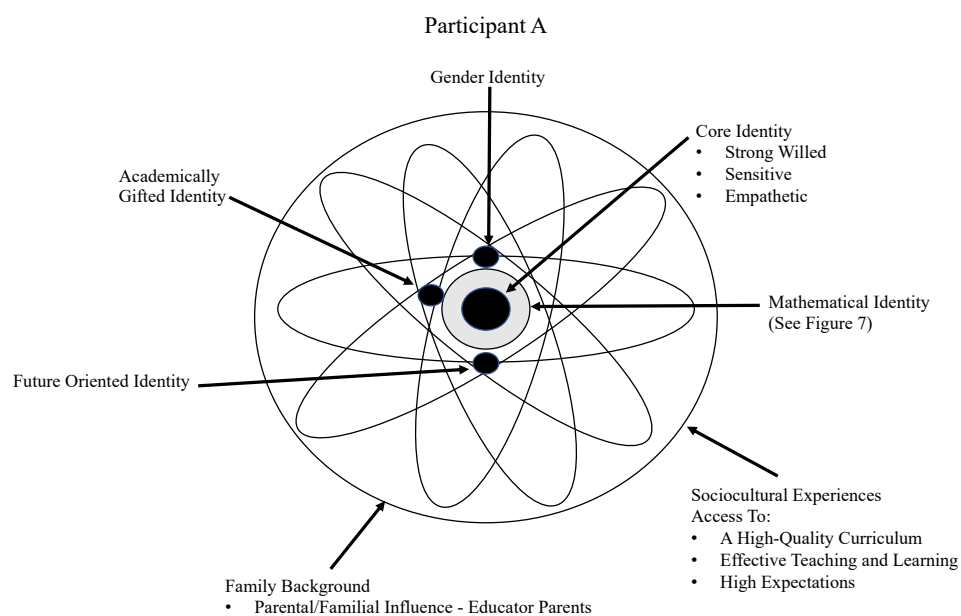


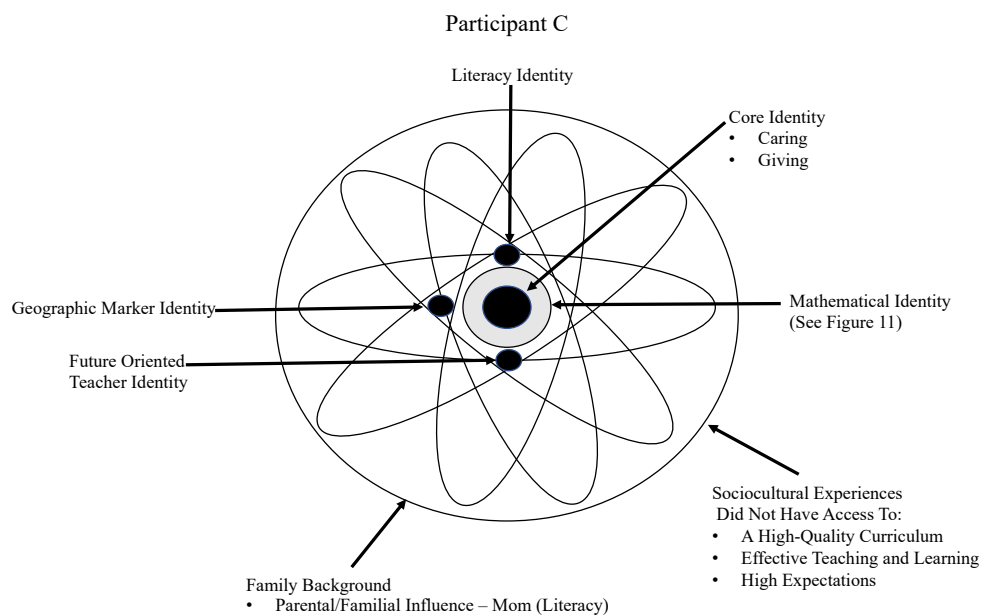
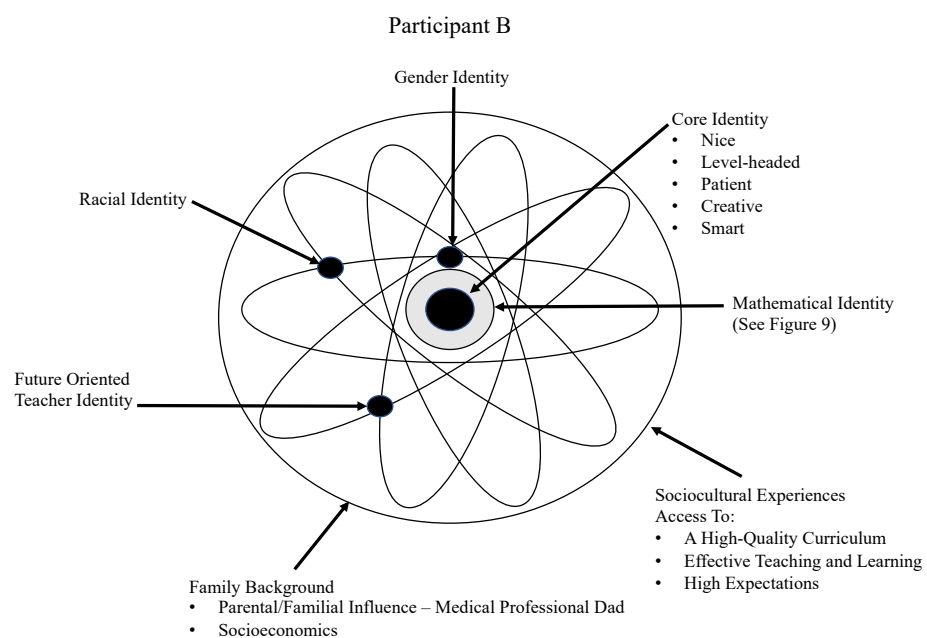




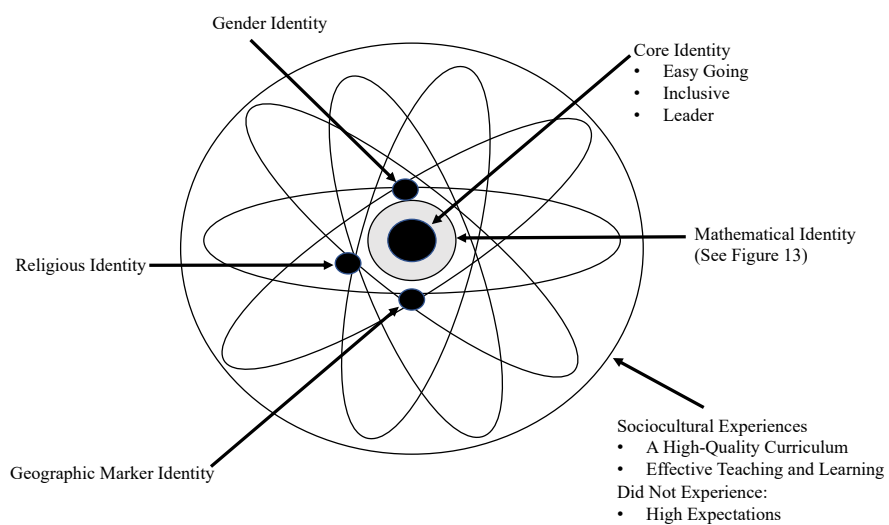


The Model of the Multiple Dimensions of Identity adapted (Jones and McEwen, 2000) was used to map each participant's salient identities and mathematics experiences that contributed to their perceptions of equity.





Participant D



Participant E

